NRC·CNRC

Construction Research Centre

Acoustical performance in multi-unit residential buildings (MURBs): current state and future considerations

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Why do we address noise in MURBs?

Noise as a public health issue (WHO):

- Increased risk of myocardial infarction, hypertension, sleep disturbance and cognitive impairment in children

- At least 1 million healthy life years lost per year
  At least 12,000 premature deaths per year
  (estimates for environmental noise in Western Europe)

Noise as a social issue (NRC):

- Poor protection from noise transmission blamed on neighbours rather than building performance

Why do we address noise in MURBs?

National Building Code of Canada (NBC):

OH3 Noise Protection

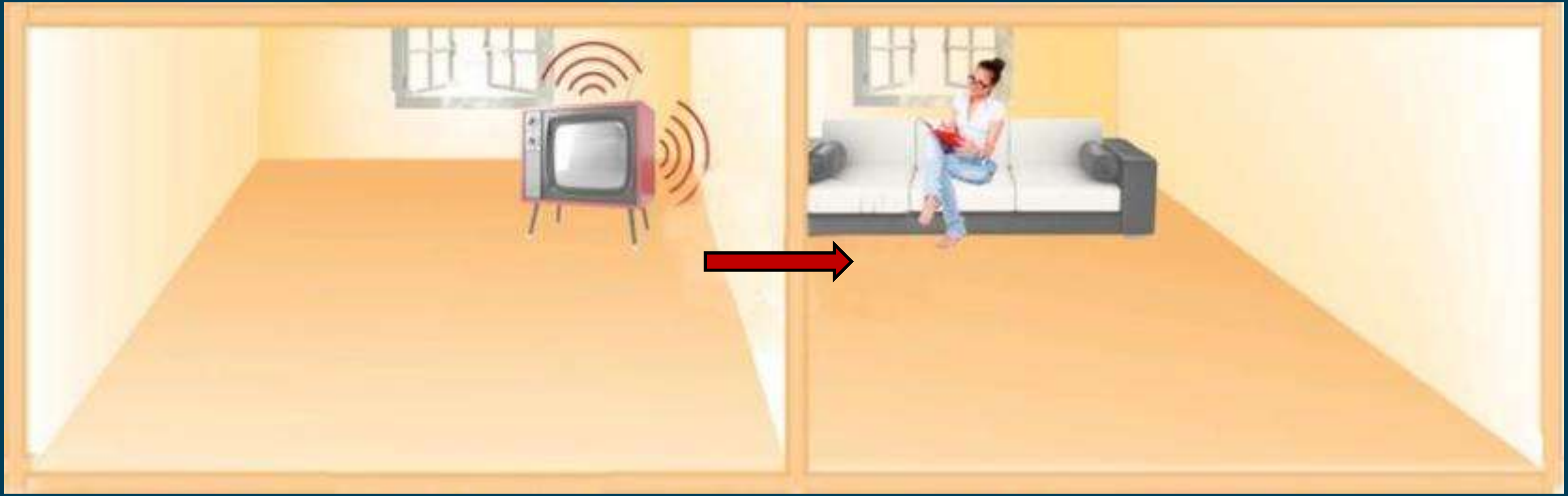
An objective of this Code is to limit the probability that, as a result of the design or construction of the *building*, a person in the *building* will be exposed to an unacceptable risk of illness due to high levels of sound originating in adjacent spaces in the *building* (see Sentence 2.1.1.2.(3) for application limitation). The risks of illness due to high levels of sound addressed in this Code are those caused by—

OH3.1 – exposure to airborne sound transmitted through assemblies separating *dwelling units* from adjacent spaces in the *building*

Acoustic performance requirements in Canada before 2015

STC ≥ 50 for the separating wall or floor/ceiling between dwellings

- To comply, simply choose a wall or floor design that meets this requirement



Acoustic performance requirements in Canada

2015 / 2020 National Building Code of Canada

Section 5.8. Sound Transmission

(See Note A-5.8.)

5.8.1. Protection from Airborne Noise

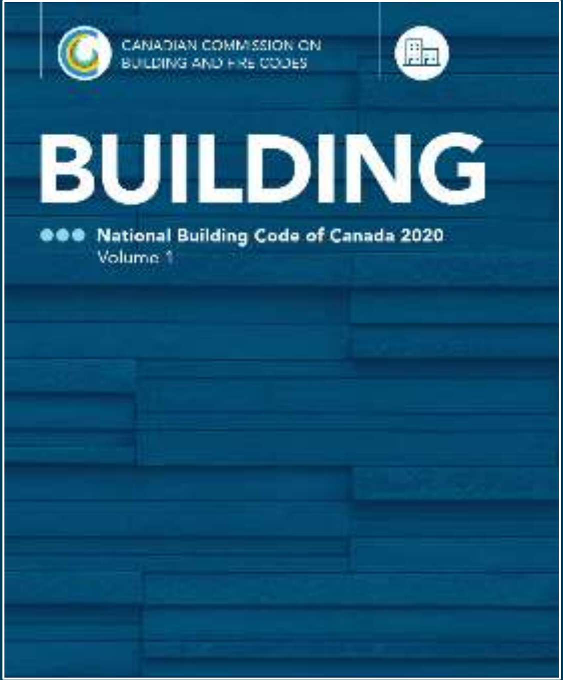
5.8.1.1. Required Protection

1) Except as provided in Sentence (2), a *dwelling unit* shall be separated from every other space in a *building* in which noise may be generated by

a) a separating assembly and adjoining constructions, which, together, provide an *apparent sound transmission class (ASTC)* rating not less than 47, or

b) a separating assembly that provides a *sound transmission class (STC)* rating of not less than 50 and adjoining constructions that conform to Article 9.11.1.4.

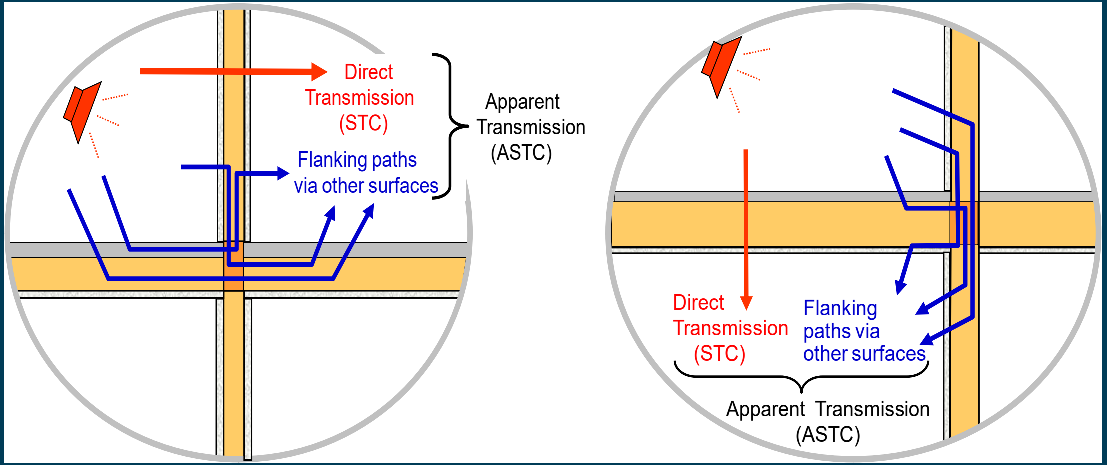
2) Construction separating a *dwelling unit* from an elevator shaft or a refuse chute shall have an *STC* rating not less than 55.



Acoustic performance requirements in Canada

The ASTC rating

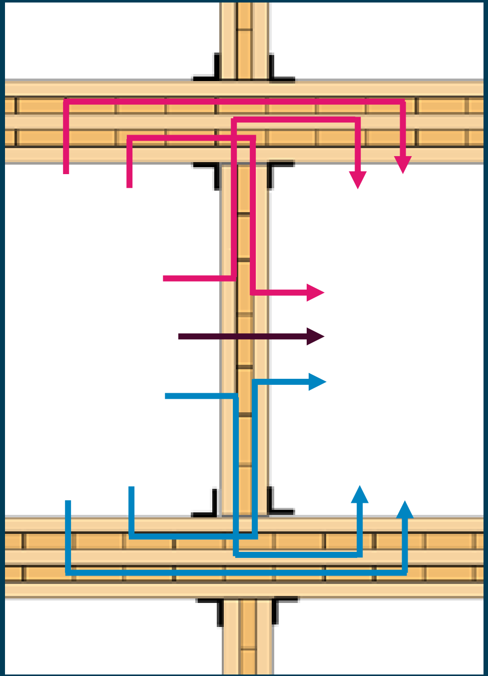
- Takes into account the direct path and all of the flanking paths
- More accurately represents what people actually experience

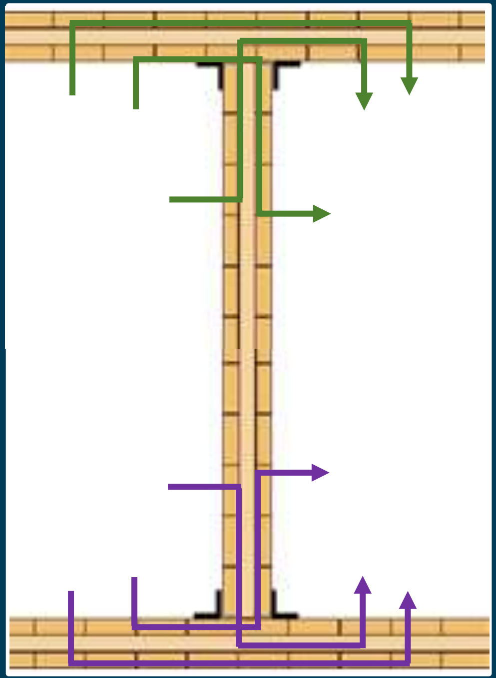


Acoustic performance requirements in Canada

Total of 12 flanking paths and one direct path for each case

Side view



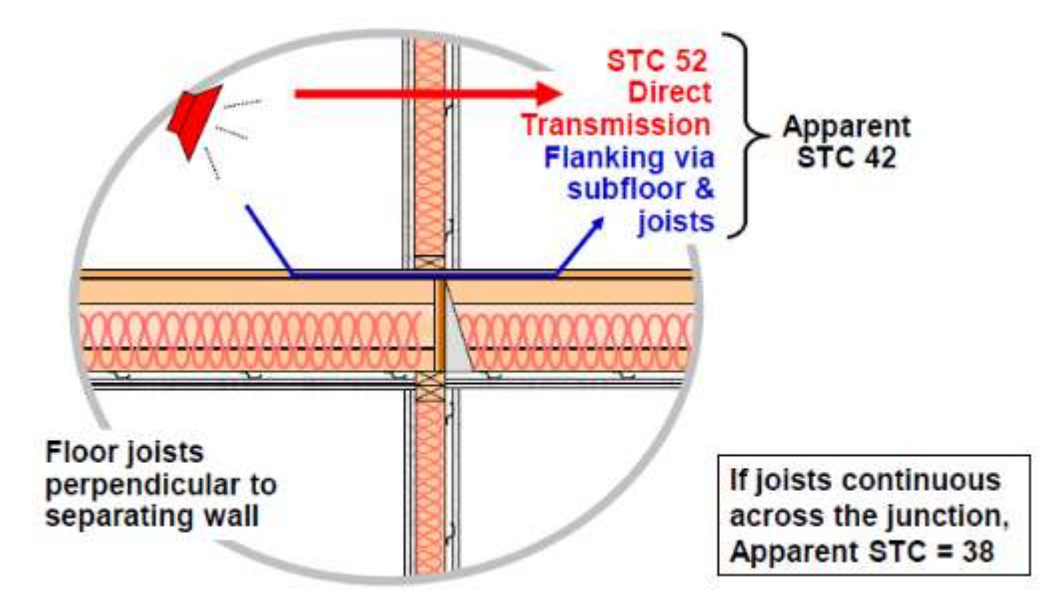


Top view

What does the ASTC rating mean for building design?

The ASTC rating cannot be determined directly from the STC rating

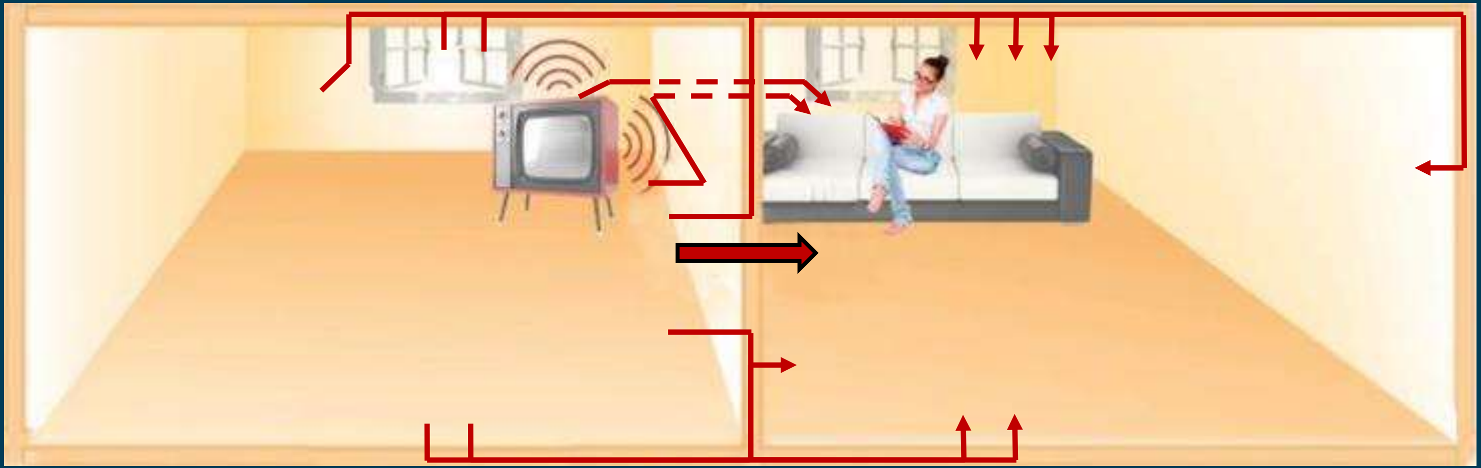
- The two ratings are not interchangeable



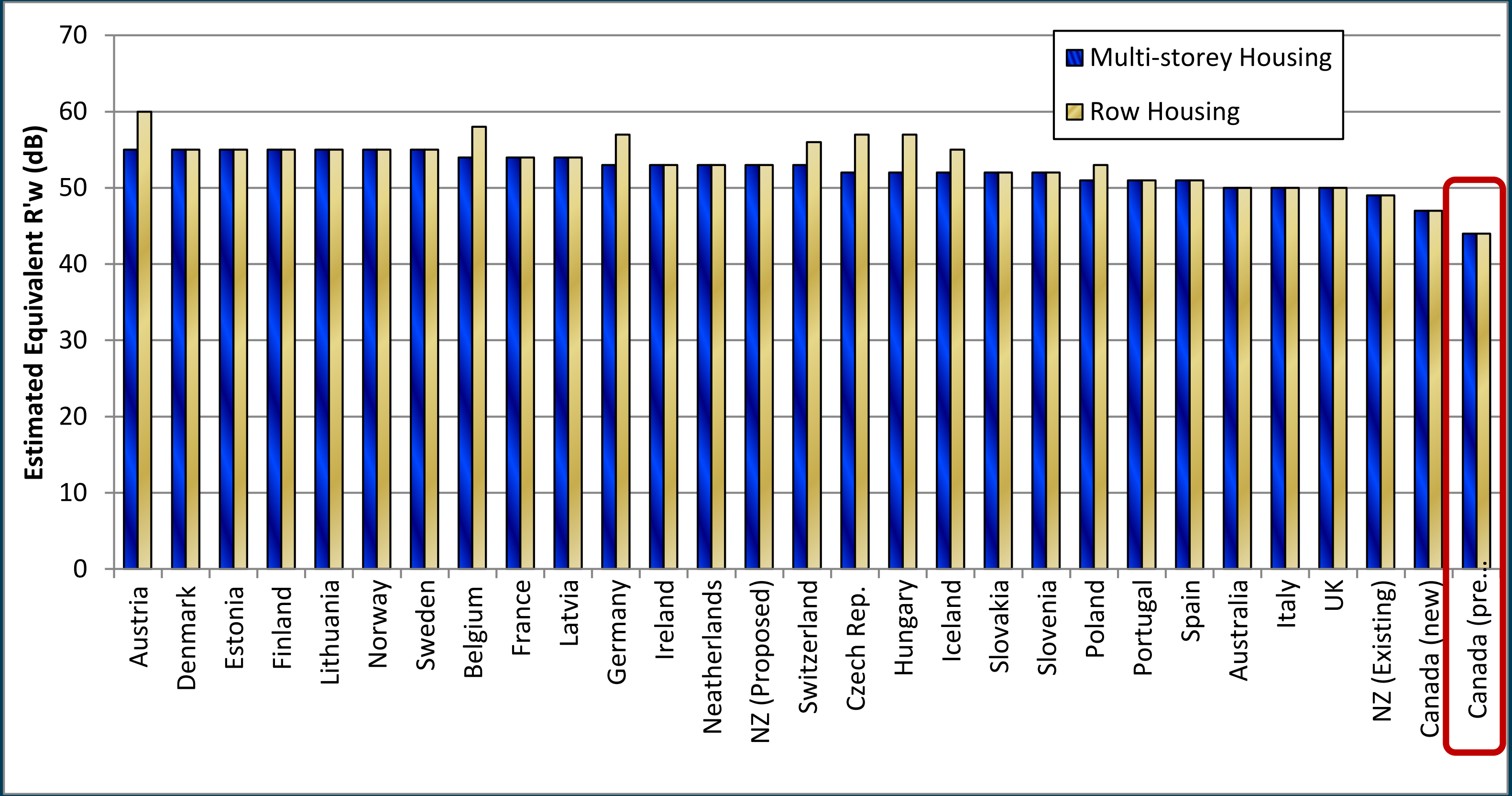
What does the ASTC rating mean for building design?

The building needs be considered as a system

- The acoustic performance of all the connected elements (walls, floors, ceilings) must be considered



Acoustic performance requirements



Acoustic performance requirements in Canada

Part 5 of the NBCC provides three paths for demonstrating compliance

1. Post completion field testing
2. Prescriptive procedure (Part 9), based on existing tables of assembly STC values plus new details for specific types of construction
3. Detailed design procedure (Part 5) which uses laboratory test data for specific assemblies and junctions

Field testing

Acoustic performance requirements in Canada

Part 5 of the NBCC provides three paths for demonstrating compliance

1. Post completion field testing
2. Prescriptive procedure (Part 9), based on existing tables of assembly STC values plus new details for specific types of construction
3. Detailed design procedure (Part 5) which uses laboratory test data for specific assemblies and junctions

Prescriptive procedure (Part 9)

Specific Requirements (9.11.1.4)

- Separating wall with STC ≥ 50
- Details for the floor / ceiling
- Details for the adjoining walls
- Details for the junctions between the elements

Possible Changes

- Options to increase the ASTC rating (Table A-9.11.1.4-B)

HORIZONTAL TRANSMISSION -1
Minimum requirements for assemblies in side-by-side spaces with separating walls W5, W6, W10, W12 (see Table A-9.10.3.1.A)

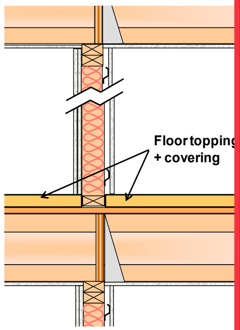
Separating wall assembly (loadbearing or non- loadbearing) with
- 38 mm x 89 mm wood studs (single row of wood studs or staggered studs on a single 38 mm x 140 mm plate)
- resilient metal channels on one side
- gypsum board, spacing of studs and resilient metal channels[1], and absorptive material[2] as required for Walls W5, W6, W10, W12 in Table A-9.10.3.1.A with STC 50 or greater

Bottom Junction (separating wall and floor) with:
- floor topping and flooring on both sides of the junction, with mass 8 kg/m^2 or greater (e.g.- 16 mm hardwood strip flooring aligned parallel to separating wall, or added layer of 16 mm OSB or plywood with any flooring on top)
- subfloor on both sides of plywood, OSB or waferboard (15.5 mm or thicker), or tongue and groove lumber (17 mm or thicker),
- floor framed with wood joists or wood I-joists or wood trusses spaced 400 mm o.c. or more, with or without absorptive material[2] in cavities
- floor joists/trusses oriented parallel to separating wall (non-loadbearing case), or perpendicular to separating wall but not continuous across junction (loadbearing case, as illustrated)

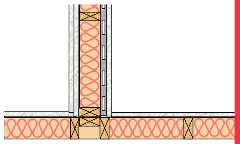
Top Junction (separating wall and ceiling) with:
- ceiling framed with wood joists, or wood I-joists, or wood trusses, with or without absorptive material[2] in cavities
- ceiling joists/trusses may be perpendicular to separating wall and not continuous across junction (loadbearing case, as illustrated) or parallel to junction (non-loadbearing case)
- gypsum board ceiling fastened directly to bottom of ceiling framing or on resilient metal channels[1]

Side Junctions (separating wall and abutting side walls) with:
- gypsum board on side walls ends or is cut at the separating wall; it may be attached directly or on resilient metal channels[1]
- side wall framing with single row of wood studs, or staggered studs on a single 38 mm x 140 mm plate, or 2 rows of 38 mm x 89 mm wood studs on separate 38 mm x 89 mm plates, with or without absorptive material[2] in cavities
- side wall framing structurally-connected to the separating wall; it may terminate where it butts against framing of the separating wall, or be continuous across junction (as illustrated)

Illustration for one case of this group



Junction of separating wall with floor and ceiling. Illustrated for separating wall W5 with wood-I joists perpendicular to the wa[ll]; other choices are possible. (Side view)



Junction of separating wall with abutting side walls illustrated for separating wall W[5] with side wall framing continuous across junction. Other choices are possible. (Plan view)

Possible changes to details to improve sound insulation beyond minimum requirement:
- Increase mass of floor topping and flooring (e.g. - concrete or gypsum concrete topping).
- Choose separating wall assembly with higher STC
- Orient floor and ceiling joists to be parallel to separating wall (non-loadbearing case).
- Add resilient layer under floor topping or between topping and flooring
- Support gypsum board panels of ceiling on resilient metal channels[1]
- Support gypsum board panels of abutting side walls on resilient metal channels[1]

Note: Suggested improvements are in approximate order of acoustic priority[3], and are inter-dependent.

Illustration for One Case (Table A-9.11.1.4-A)

- Not the only acceptable case, but serves to illustrate the elements

Prescriptive procedure (Part 9)

- Requires key construction details for the flanking elements
- Limited set of choices

Acoustic performance requirements in Canada

Part 5 of the NBCC provides three paths for demonstrating compliance

1. Post completion field testing

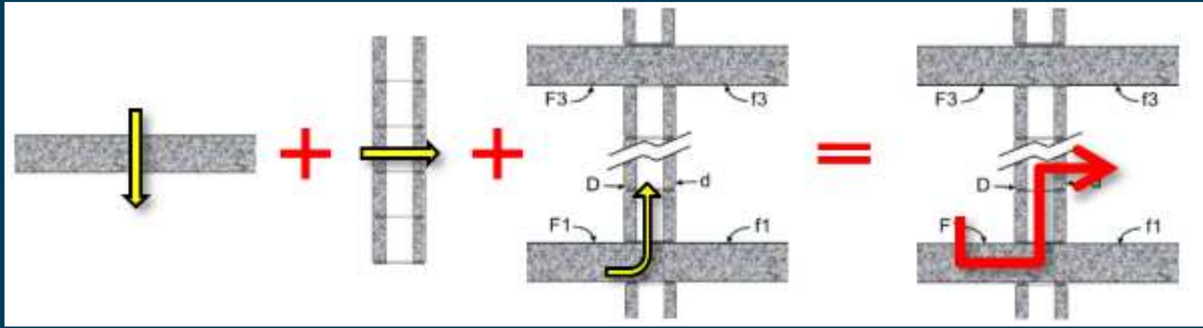
2. Prescriptive procedure (Part 9), based on existing tables of assembly STC values plus new details for specific types of construction

3. Detailed design procedure (Part 5), which uses laboratory test data for specific assemblies and junctions

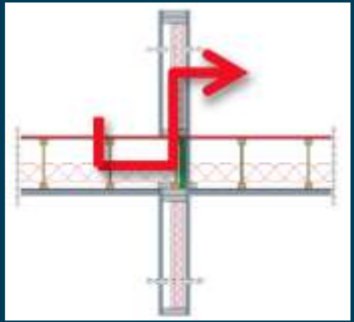
Detailed design procedure (Part 5)

The ASTC rating is calculated using the method described in ISO 12354-1, previously ISO 15712-1

Heavy, homogeneous construction



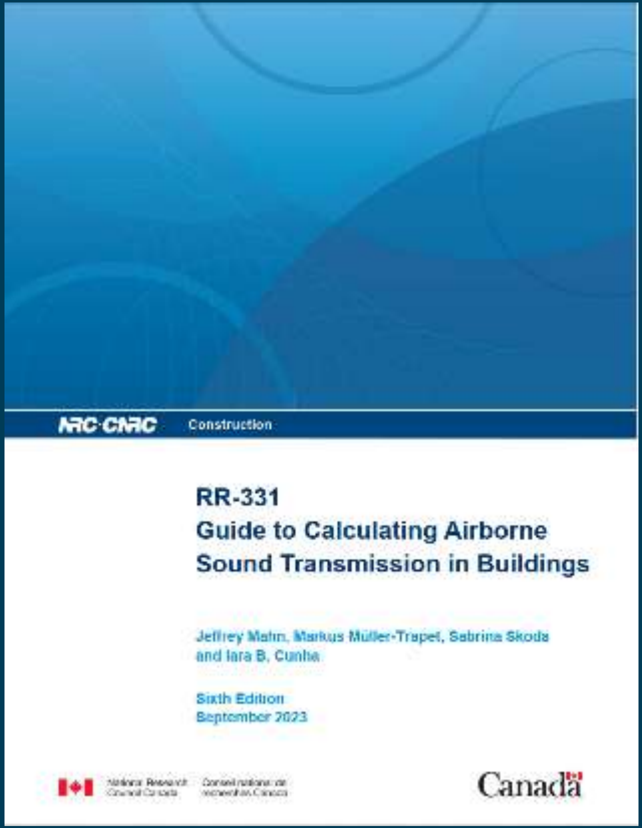
Light-frame construction



Detailed design procedure (Part 5)

Described in Research Report RR-331

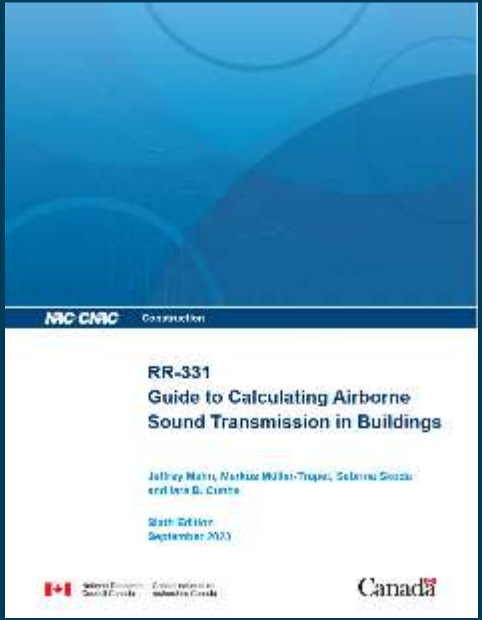
Sixth edition (2023):
https://doi.org/10.4224/40003444



Research Report RR-331

https://doi.org/10.4224/40003444

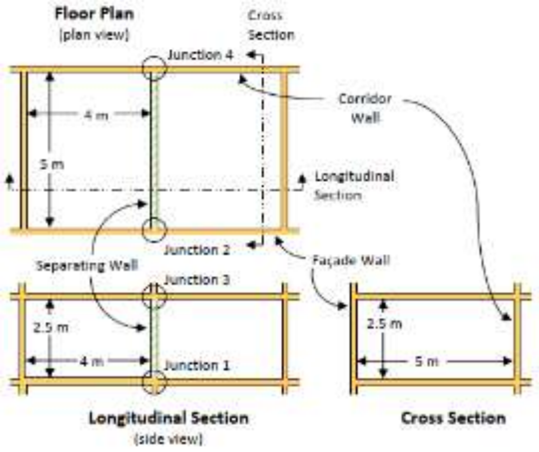
One of the outputs of industry-supported SIG ASTC

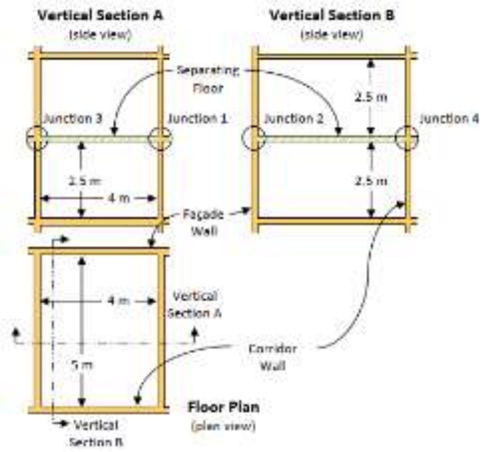


Research Report RR-331

https://doi.org/10.4224/40003444

- Explains the ASTC rating
- Presents the equations used for the calculations
- Explains how to calculate improvements due to toppings or linings
- Step by step instructions to calculate the ASTC rating for different construction types

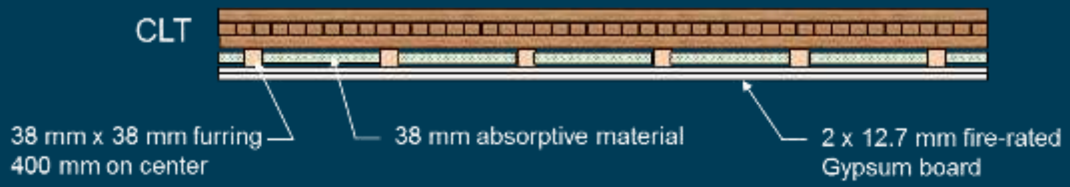




Research Report RR-331

Linings for building elements

- The term linings is used for:
  - Toppings on floors
  - Linings on walls or ceilings



Research Report RR-331

Linings for building elements

- For heavy, homogeneous constructions a change due to the lining is presented
  - Concrete
  - Mass Timber

- The data is presented either in 1/3 octave bands or as a single number rating ΔSTC

Code	Description	ΔSTC
ΔTL-BLK(NW)-61	AIR13_SS65(610)_G13	2
ΔTL-BLK(NW)-62	AIR13_SS65(610)_GFB65_G13	19
ΔTL-BLK(NW)-63	AIR13_SS65(610)_GFB65_2G13	22

Research Report RR-331

Linings for building elements

- For lightweight constructions
  - Timber framed
  - Lightweight steel studs

- The improvements due to linings can not be calculated separately, but must be part of the measurements on the structure.

- The ΔSTC can not be used

EXAMPLE 4.2.8: **SIMPLIFIED METHOD**

- **Rooms side-by-side**
- **Wood-framed walls and floors**
- **Double stud separating wall**

Separating wall element.

- Double row of 38 mm x 89 mm wood studs spaced 16" (406 mm) on center with a 1" (25.4 mm) space between the rows. 89 mm-thick sound absorbing material[4] filling the inter stud cavities of both rows.
- One layer of 15.8 mm thick fire-rated gypsum board[3] attached directly to the framing on both sides.

Two options are compared:

Case A The OSB subfloor is continuous across the floor and ceiling junctions as shown in the upper detail.

Case B The OSB subfloor is not continuous across the junctions as shown in the lower detail.

Junction 1: Cross-junction between the separating wall and the floor:

- A wood-framed floor of 2 x 10 (38 mm x 235 mm) wood joists spaced 16" (406 mm) on center with joists not continuous across the junction. 150 mm thick absorptive material[4] in the inter-joist cavities.
- Subfloor of oriented strand board (OSB) 19 mm thick
- No floor topping

Junction 2 or 4: T-junction between the separating wall and the side wall:

- Abutting side walls framed with a single row of 38 mm x 89 mm wood studs spaced 16" (406 mm) on center with 89 mm-thick sound absorbing material[4] filling the inter-stud cavities.
- Side wall framing structurally-connected to the separating wall and continuous across the junction (as illustrated)
- One layer of 15.8 mm thick fire-rated gypsum board[3] supported on resilient channels[5] spaced 16" (406 mm) on center and terminating at the separating wall.

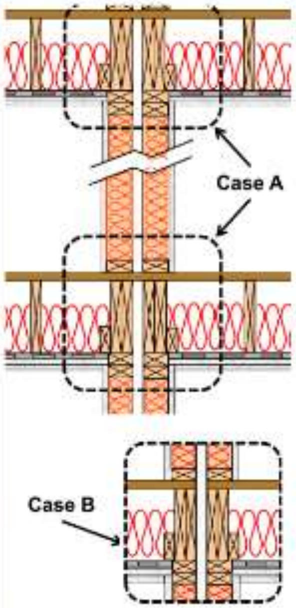
Junction 3: Cross junction between the separating wall and the ceiling

- Ceiling of 10" (235 mm) wood joists, same as for Junction 1.
- Ceiling of two layers of 15.8 mm thick fire-rated gypsum board[3] supported on resilient channels spaced 16" (406 mm) on center.

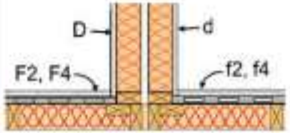
Acoustical Parameters:

	In-situ Values	Laboratory Values
Area of the Separating Element (m^2) =	12.5	12.5
Floor/separating wall junction length (m) =	5.0	5.0
Wall/separating wall junction length (m) =	2.5	2.5
Normalization For Junctions 1 and 3:		
$10\log(S_{s,situ}/S_{s,lab}) + 10\log(l_{ij,lab}/l_{ij,situ})$ =	0	RR-331 Equation 4.10
Normalization For Junctions 2 & 4:		
$10\log(S_{s,situ}/S_{s,lab}) + 10\log(l_{ij,lab}/l_{ij,situ})$ =	0	RR-331 Equation 4.10

Illustration for this case



Two options for the cross junction between the wood-framed separating wall and the wood joist floor and ceiling. (Side view of Junctions 1 and 3)



T-junction between the separating wall and the abutting side walls. The framing of the side wall is continuous across the junction. The gypsum board of the side wall terminates at the junction with the separating wall. (Plan view of Junction 2 or 4)

Note: For this example, the flanking sound transmission loss data for the individual paths at each junction is not availabe. Thefore, the example uses the available data for the junction.

CASE A: OSB Subfloor is Continuous under the Separating Wall

	Symbol	Reference	STC or ΔSTC		STC or ASTC
Separating Wall					
Laboratory STC for Dd	$STC_{Dd,lab}$	RR-336: DWS89-WF-NLB-1-1-2	57		
ΔSTC rating for the Lining on D	ΔSTC_D	Not a floor assembly. No ΔSTC correction			
Direct STC Dd	STC_{Dd}	RR-331 Equation 4.7			57
Junction 1: Junction between the separating wall and the floor					
Laboratory Flanking STC Rating	$STC_{ij,lab}$	RR-336: DWS89-WF-NLB-1-1-2	47		
Total Flanking STC Rating for Junction 1		RR-331 Equation 4.10		47 + 0 =	47
Junction 2: Junction between the separating wall and the abutting facade wall					
Measured Laboratory Flanking STC	$STC_{ij,lab}$	RR-336: DWS89-WW-1-1R	68		
Total Flanking STC Rating for Junction 2		RR-331 Equation 4.10		68 + 0 =	68
Junction 3: Junction between the separating wall and the ceiling					
Measured Laboratory Flanking STC	$STC_{ij,lab}$	RR336: DWS89-WC-NLB-1-1-2	62		
Total Flanking STC Rating for Junction 3		RR-331 Equation 4.10		62 + 0 =	62
Junction 4: Junction between the separating wall and the abutting corridor wall					
Measured Laboratory Flanking STC	$STC_{ij,lab}$	RR336: DWS89-WW-1-1R	68		
Total Flanking STC Rating for Junction 4		RR-331 Equation 4.10		68 + 0 =	68
Total Flanking STC Rating for All of the Junctions			Combining the Values from the 12 Flanking Paths		47
ASTC Rating		RR-331 Equation 1.2	Combining Direct STC with 12 Flanking STC	46	

CASE B: OSB Subfloor is Discontinuous

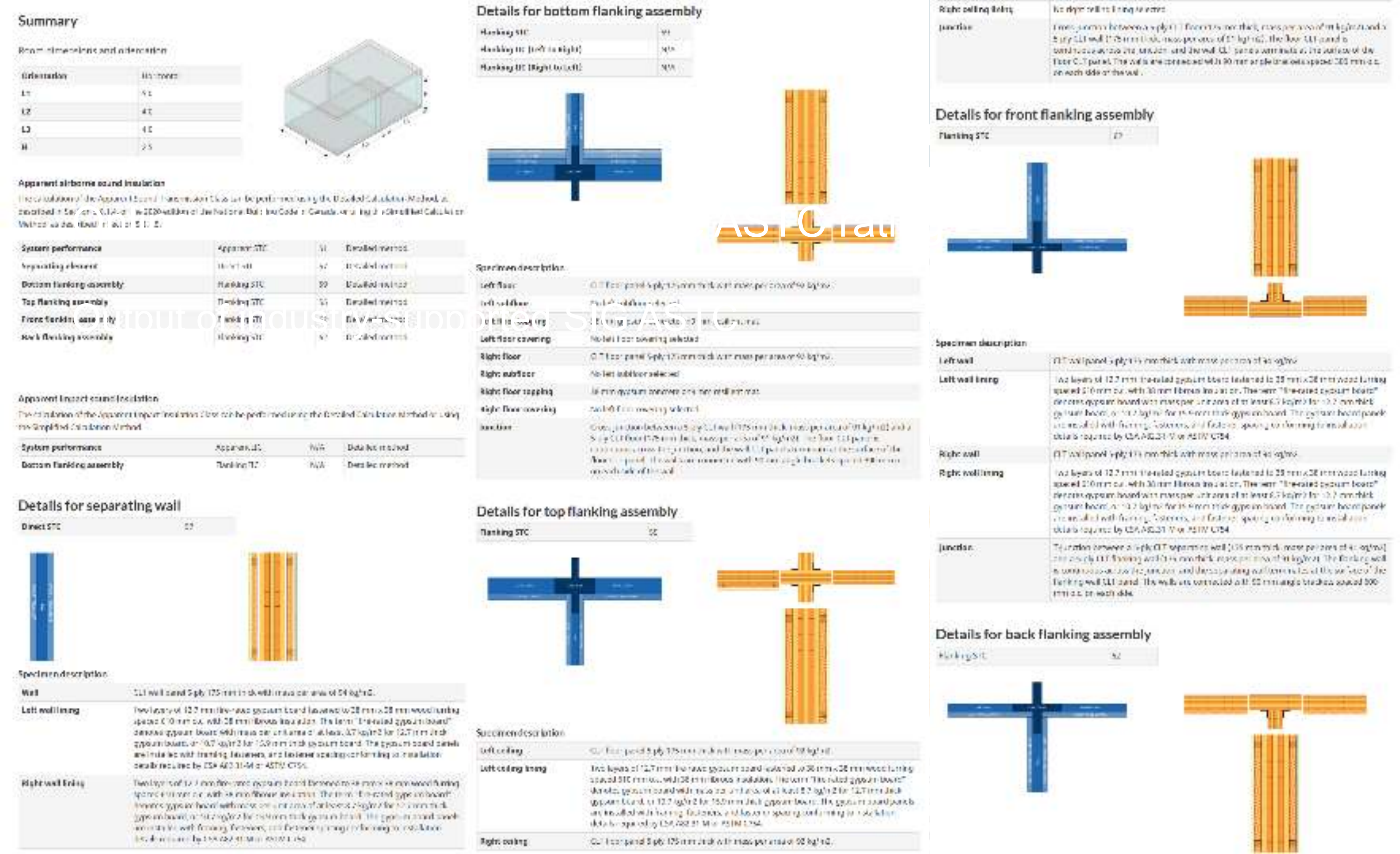
	Symbol	Reference	STC or ΔSTC		STC or ASTC
Separating Wall					
Laboratory STC for Dd	$STC_{Dd,lab}$	RR-336: DWS89-WF-NLB-2-1-2	57		
ΔSTC rating for the Lining on D	ΔSTC_D	Not a floor assembly. No ΔSTC correction			
Direct STC Dd	STC_{Dd}	RR-331 Equation 4.7			57
Junction 1: Junction between the separating wall and the floor					
Laboratory Flanking STC Rating	$STC_{ij,lab}$	RR-336: DWS89-WF-NLB-2-1-2	85		
Total Flanking STC Rating for Junction 1		RR-331 Equation 4.10		85 + 0 =	85
Junction 2: Junction between the separating wall and the abutting facade wall					
Measured Laboratory Flanking STC	$STC_{ij,lab}$	RR-336: DWS89-WW-1-1R	68		
Total Flanking STC Rating for Junction 2		RR-331 Equation 4.10		68 + 0 =	68
Junction 3: Junction between the separating wall and the ceiling					
Measured Laboratory Flanking STC	$STC_{ij,lab}$	RR336: DWS89-WC-NLB-2-1-2	85		
Total Flanking STC Rating for Junction 3		RR-331 Equation 4.10		85 + 0 =	85
Junction 4: Junction between the separating wall and the abutting corridor wall					
Measured Laboratory Flanking STC	$STC_{ij,lab}$	RR336: DWS89-WW-1-1R	68		
Total Flanking STC Rating for Junction 4		RR-331 Equation 4.10		68 + 0 =	68
Total Flanking STC Rating for All of the Junctions			Combining the Values from the 12 Flanking Paths		65
ASTC Rating		RR-331 Equation 1.2	Combining Direct STC with 12 Flanking STC	56	

Research Report RR-331

RR-331 describes two calculation methods:

- Simplified – uses single number ratings (STC, ΔSTC)
- Detailed – uses data in 1/3 octave bands between 125 Hz and 4000 Hz

- Concrete construction: transfer lab → in-situ values only in detailed method → higher in-situ performance
- Generally: better prediction for linings with detailed method



Summary

Room dimensions and orientation

Orientation	Horizontal
L1	5.1
L2	4.1
L3	4.1
H	2.5

Apparent airborne sound insulation

The calculation of the Apparent Sound Transmission Class can be performed using the Detailed Calculation Method as described in Section 5.8.1 of the 2020 edition of the National Building Code of Canada, or using the Simplified Calculation Method as described in Section 5.8.1.

System performance	Apparent STC	51	Detailed method
Separating element	Direct STC	57	Detailed method
Bottom flanking assembly	Flanking STC	59	Detailed method
Top flanking assembly	Flanking STC	55	Detailed method
Front flanking assembly	Flanking STC	[illegible]	Detailed method
Back flanking assembly	Flanking STC	57	Detailed method

Apparent impact sound insulation

The calculation of the Apparent Impact Insulation Class can be performed using the Detailed Calculation Method or using the Simplified Calculation Method.

System performance	Apparent IIC	N/A	Detailed method
Bottom flanking assembly	Flanking IIC	N/A	Detailed method

Details for separating wall

Direct STC	57

Specimen description

Wall	CLT wall panel 5-ply 175 mm thick with mass per unit area of 84 kg/m2.
Left wall lining	Two layers of 12.7 mm fire-rated gypsum board fastened to 38 mm x 38 mm wood furring spaced 610 mm o.c. with 38 mm fibrous insulation. The term "fire-rated gypsum board" denotes gypsum board with mass per unit area of at least 8.7 kg/m2 for 12.7 mm thick gypsum board, or 10.7 kg/m2 for 15.9 mm thick gypsum board. The gypsum board panels are installed with framing, fasteners, and fastener spacing conforming to installation details required by CSA A82.31-M or ASTM C754.
Right wall lining	[illegible]

Details for bottom flanking assembly

Flanking STC	59
Flanking IIC (Left to Right)	N/A
Flanking IIC (Right to Left)	N/A

Specimen description

Left floor	CLT floor panel 5-ply 175 mm thick with mass per unit area of 90 kg/m2.
Left subfloor	No left subfloor selected
Left floor topping	[illegible]
Left floor covering	No left floor covering selected
Right floor	CLT floor panel 5-ply 175 mm thick with mass per unit area of 90 kg/m2.
Right subfloor	No left subfloor selected
Right floor topping	[illegible]
Right floor covering	No left floor covering selected
Junction	[illegible]

Details for top flanking assembly

Flanking STC	55

Specimen description

Left ceiling	CLT floor panel 5-ply 175 mm thick with mass per unit area of 90 kg/m2.
Left ceiling lining	Two layers of 12.7 mm fire-rated gypsum board fastened to 38 mm x 38 mm wood furring spaced 610 mm o.c. with 38 mm fibrous insulation. [illegible]
Right ceiling	CLT floor panel 5-ply 175 mm thick with mass per unit area of 90 kg/m2.
Right ceiling lining	No right ceiling lining selected
Junction	[illegible]

Details for front flanking assembly

Flanking STC	[illegible]

Specimen description

Left wall	CLT wall panel 5-ply 175 mm thick with mass per unit area of [illegible] kg/m2.
Left wall lining	Two layers of 12.7 mm fire-rated gypsum board fastened to 38 mm x 38 mm wood furring spaced 610 mm o.c. with 38 mm fibrous insulation. The term "fire-rated gypsum board" denotes gypsum board with mass per unit area of at least 8.7 kg/m2 for 12.7 mm thick gypsum board, or 10.7 kg/m2 for 15.9 mm thick gypsum board. The gypsum board panels are installed with framing, fasteners, and fastener spacing conforming to installation details required by CSA A82.31-M or ASTM C754.
Right wall	CLT wall panel 5-ply 175 mm thick with mass per unit area of [illegible] kg/m2.
Right wall lining	Two layers of 12.7 mm fire-rated gypsum board fastened to 38 mm x 38 mm wood furring spaced 610 mm o.c. with 38 mm fibrous insulation. The term "fire-rated gypsum board" denotes gypsum board with mass per unit area of at least 8.7 kg/m2 for 12.7 mm thick gypsum board, or 10.7 kg/m2 for 15.9 mm thick gypsum board. The gypsum board panels are installed with framing, fasteners, and fastener spacing conforming to installation details required by CSA A82.31-M or ASTM C754.
Junction	[illegible]

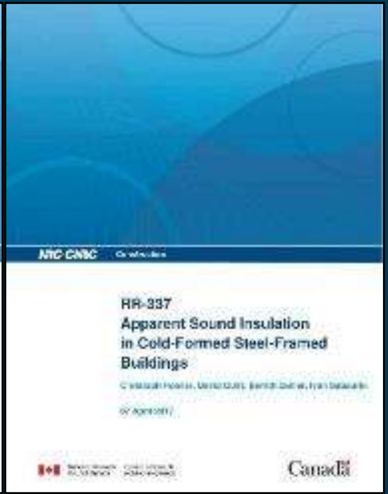
Details for back flanking assembly

Flanking STC	57

Output of industry-supported SIG ASTC [illegible]

Publications with the data

RR-331 + soundPATHS supported by:



Updates to most of these in progress!

Conclusion – ASTC

ASTC requirements adopted in all provinces and territories

Considering flanking transmission results in

- Better design that takes perceived performance into account
- Cost-effective solutions (less overdesign, less remediation)

NRC-developed, industry-supported tools available

Continuous updates, when new research + data is available

Impact sound – Everyone‘s upstairs neighbors

Impact noise in MURBs

- Big(gest) source of residential complaints
- Canada one of the last countries without protection against impact sound in the building code
- Increased exposure due to Covid-19 pandemic and increase in Working-From-Home arrangements

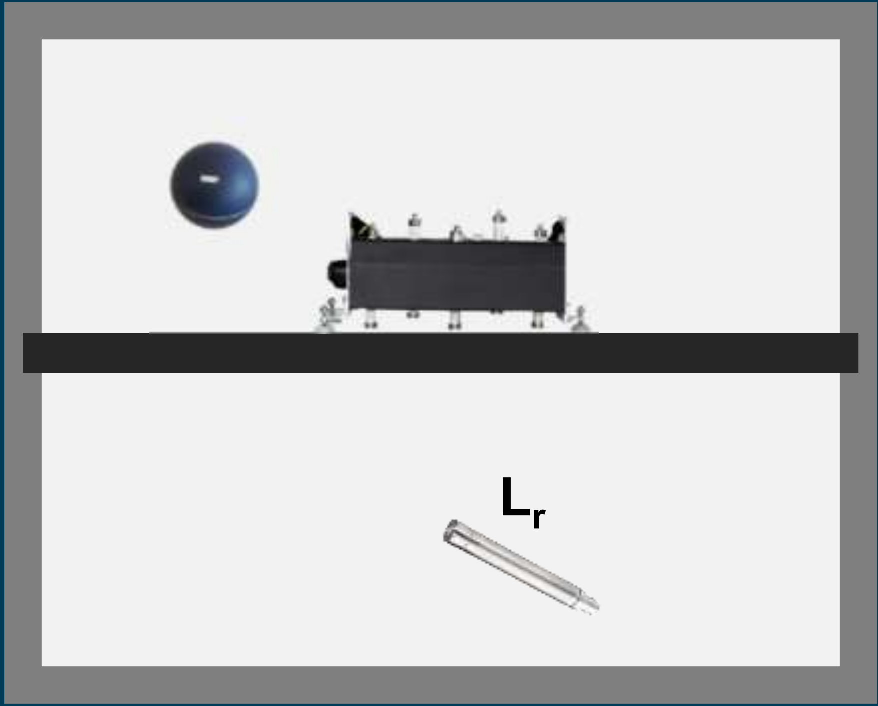
- Continuation of progress made with NBC 2015 change to ASTC
- Codes system: code change request received, task accepted

Impact noise – what it is and how to measure it

Impulsive sounds, generated
by contact with the floor surface

Measured using

- Tapping machine: NISPL, (A)IIC
- Rubber ball: $L_{iAF,max}$



Field study (with Carleton/UofT)

Determine status quo in Canadian buildings

- Airborne and impact sound
- Outdoor-indoor noise

MURBs in GTA and Ottawa

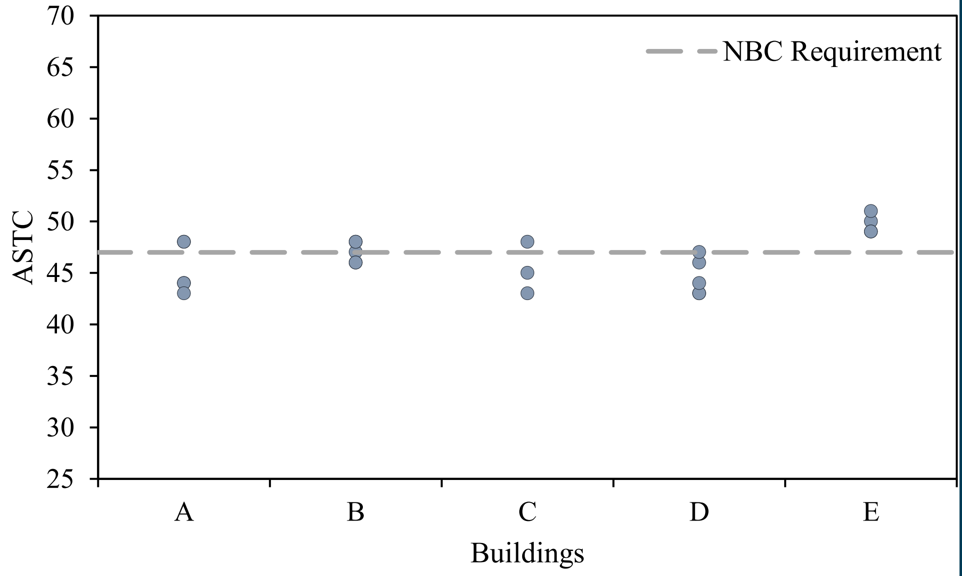
- Acoustic measurements in unoccupied buildings
- Follow-up survey once buildings were occupied

Field study (with Carleton/UofT)

Building	Construction completion year	No. of floors	No. of units (occupants)	Floor construction	Wall construction
A	1969	6	288 units (304 occupants)	Linoleum flooring + 160 mm concrete slab with concrete topping (Approximation from available drawings)	Two types of walls: Concrete sheer wall + lath + plaster, and Hollow stud wall
B	2003	8	260 units (237 occupants)	200 mm concrete slab (Information about floor finish not available)	Two layers of 16 mm gypsum board + metal stud + 152 mm batt insulation + 16 mm gypsum board
C	2021	6	50 units	Wood finish resilient plank + 254 mm hollow-core concrete slab	Two layers of 16 mm gypsum board + metal stud + 92 mm sound attenuation fire blanket insulation + Two layers of 16 mm gypsum board
D	1967 (Retrofitted in 2021)	18	146 units	Vinyl flooring + 204 mm concrete slab	3mm gypsum board + 9.5 mm gypsum board + 152 mm concrete block + 9.5 mm gypsum board+ metal stud + 16 mm gypsum board
E	2021	6	108 units	Vinyl flooring + acoustic underlay + 250 mm concrete slab	Two layers of 16 mm gypsum board + metal studs + 89 mm acoustic batt insulation + air space + metal stud + 89 mm acoustic batt insulation + Two layers of 16 mm gypsum board

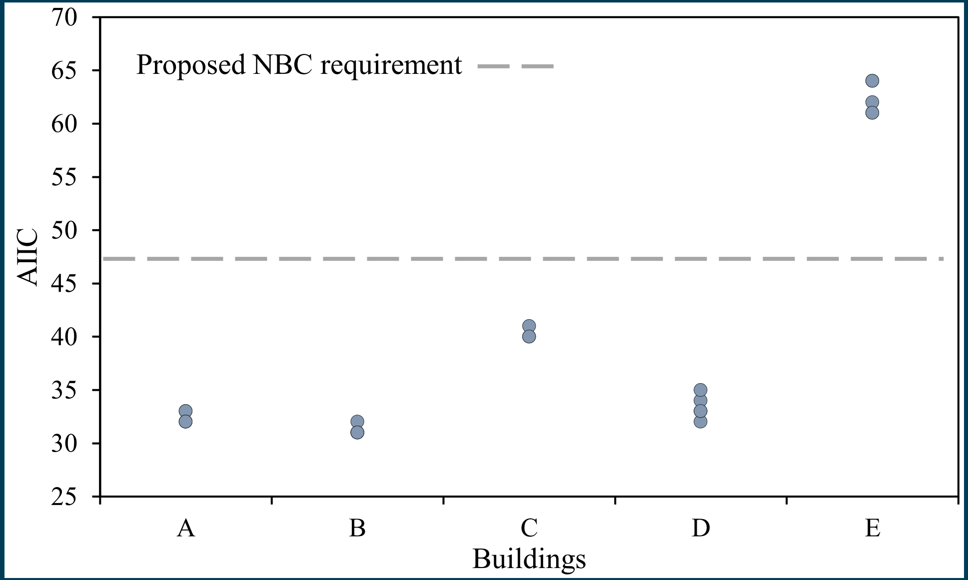
Field study (with Carleton/UofT)

Airborne sound transmission results (vs ASTC 47)



Field study (with Carleton/UofT)

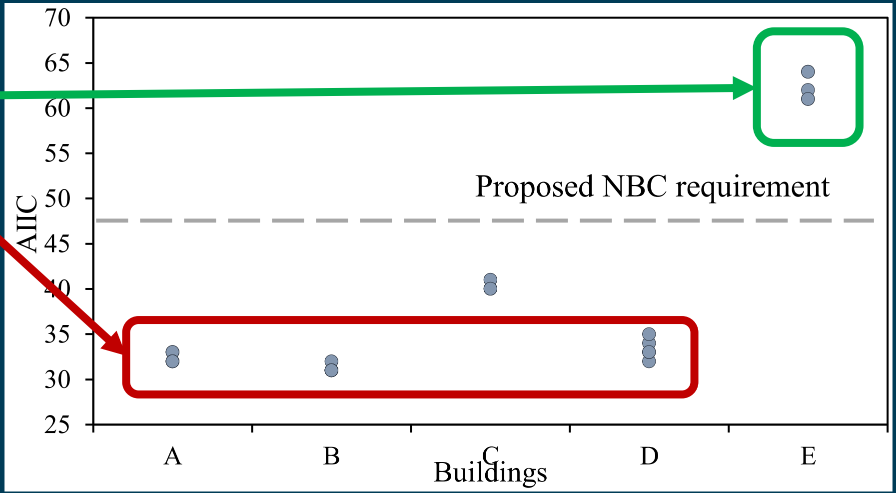
Impact sound transmission results (vs AIIC 47)



Field study (with Carleton/UofT)

Field test results show

- Urgency of problem
- Easily achievable successes



Background / current NRC research

Understand connection between perceived annoyance and standardized measurements
→ building codes

Laboratory studies under different conditions and in different countries

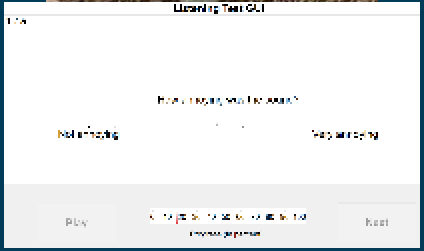
Key questions:

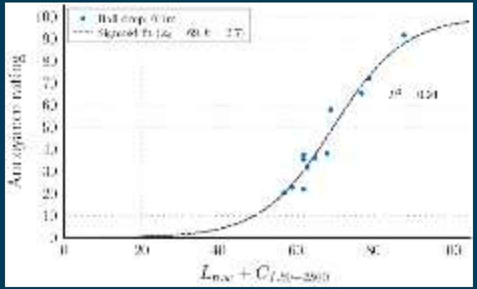
- Which rating metric is the best predictor of annoyance?
- What is the difference between impact sources?

Laboratory study of impact noise

Floor testing facility

Anechoic chamber





Laboratory study of impact noise

5 impact sources

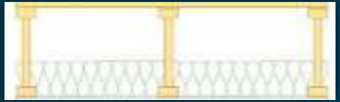
hammer drops

12 floor-ceiling assemblies

CLT

or

LW timber frame



+

different toppings / linings

	IIC	L_{iAFmax}
Min	24	53
Max	59	81

Listening experiments – in the lab

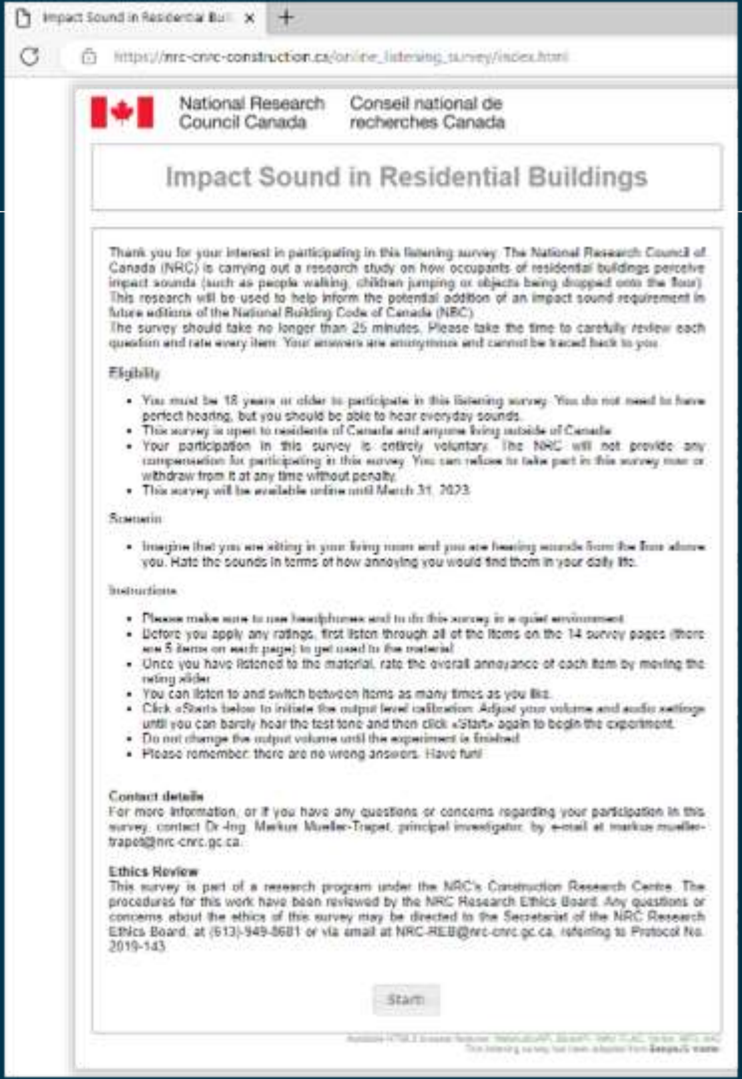
Participants:

- Canada: 26
- Korea: 30
- Germany: 30 / 20 / 30

Age range: 20 – 70 years

Listening experiments – not in the lab …

Online listening survey



Impact Sound in Residential Bu...

https://nrc-cnrc-construction.ca/online_listening_survey/index.html

National Research Council Canada

Conseil national de recherches Canada

Impact Sound in Residential Buildings

Thank you for your interest in participating in this listening survey. The National Research Council of Canada (NRC) is carrying out a research study on how occupants of residential buildings perceive impact sounds (such as people walking, children jumping or objects being dropped onto the floor). This research will be used to help inform the potential addition of an impact sound requirement in future editions of the National Building Code of Canada (NBC).
The survey should take no longer than 25 minutes. Please take the time to carefully review each question and rate every item. Your answers are anonymous and cannot be traced back to you.

Eligibility

- You must be 18 years or older to participate in this listening survey. You do not need to have perfect hearing, but you should be able to hear everyday sounds.
- This survey is open to residents of Canada and anyone living outside of Canada.
- Your participation in this survey is entirely voluntary. The NRC will not provide any compensation for participating in this survey. You can refuse to take part in this survey now or withdraw from it at any time without penalty.
- This survey will be available online until March 31, 2023.

Scenario

- Imagine that you are sitting in your living room and you are hearing sounds from the floor above you. Rate the sounds in terms of how annoying you would find them in your daily life.

Instructions

- Please make sure to use headphones and to do this survey in a quiet environment.
- Before you apply any ratings, first listen through all of the items on the 14 survey pages (there are 5 items on each page) to get used to the material.
- Once you have listened to the material, rate the overall annoyance of each item by moving the rating slider.
- You can listen to and switch between items as many times as you like.
- Click «Start» below to initiate the output level calibration. Adjust your volume and audio settings until you can barely hear the test tone and then click «Start» again to begin the experiment.
- Do not change the output volume until the experiment is finished.
- Please remember: there are no wrong answers. Have fun!

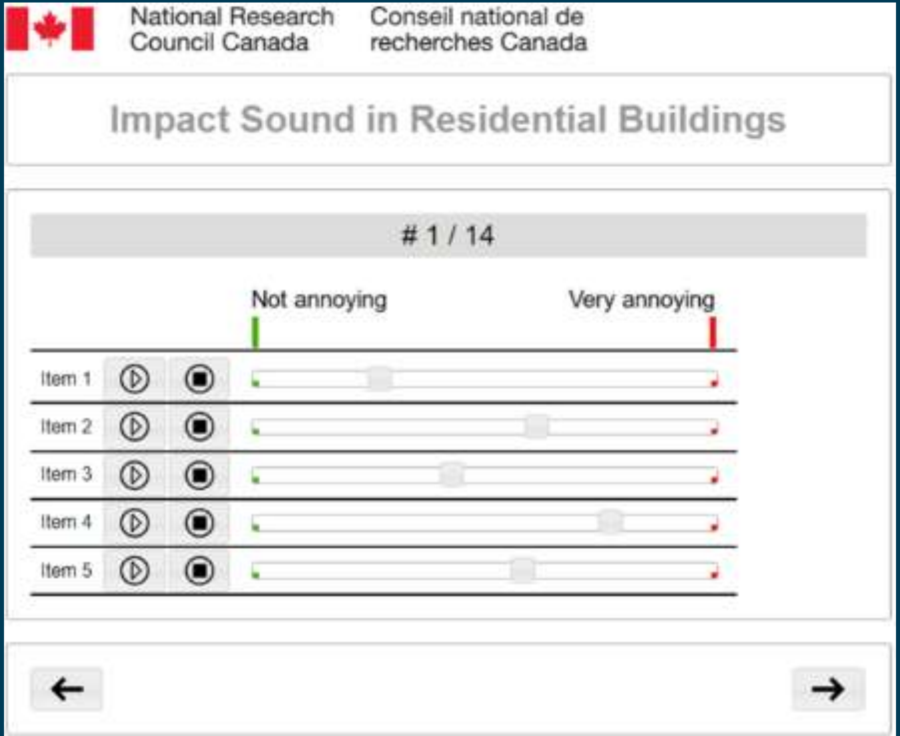
Contact details
For more information, or if you have any questions or concerns regarding your participation in this survey, contact Dr.-Ing. Markus Mueller-Trapet, principal investigator, by e-mail at markus.mueller-trapet@nrc-cnrc.gc.ca.

Ethics Review
This survey is part of a research program under the NRC's Construction Research Centre. The procedures for this work have been reviewed by the NRC Research Ethics Board. Any questions or concerns about the ethics of this survey may be directed to the Secretariat of the NRC Research Ethics Board, at (613)-949-8681 or via email at NRC-REB@nrc-cnrc.gc.ca, referring to Protocol No. 2019-143.

Start

Online listening survey

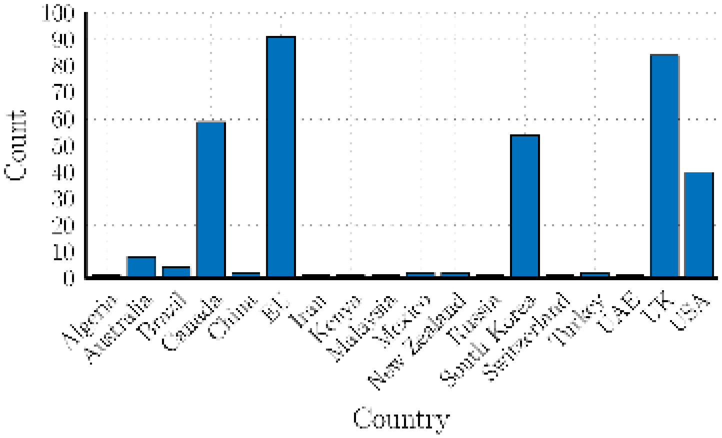
Rating procedure



Online listening survey

Post-survey questionnaire

- Country of residence, age
- Hearing ability, equipment used
- Living situation
- Noise sensitivity



National Research Council Canada
Conseil national de recherches Canada

Impact Sound in Residential Buildings

Thank you for taking the time to participate in this listening survey!
Please fill out the questionnaire below to provide some additional information.
When you are finished, please click «Submit» at the bottom of the page.

Post-survey Questionnaire

General information	
What is your country of residence?	
How old are you?	
What is your gender?	<Prefer to self-describe>
Do you experience hearing loss?	
Questions / Statements about this listening survey	
What type of headphone did you use for this listening survey?	
If known, enter your headphone model	
How authentic (i.e.: similar to sounds heard in an actual building) did the acoustic environment sound to you?	
The instructions asked that you imagine yourself in your living room. How well were you able to put yourself into the living room situation?	
How much do you agree or disagree with the following statements?	
The survey was too long.	
I felt stressed during the survey.	
The instructions were clear.	
The sounds were too loud.	
Questions / Statements about your current home	
What best describes your home?	
For how long have you lived in your current home?	
Do you rent or own your home?	
How many full-time occupants (including yourself) are part of your household?	

Listening experiments – Results

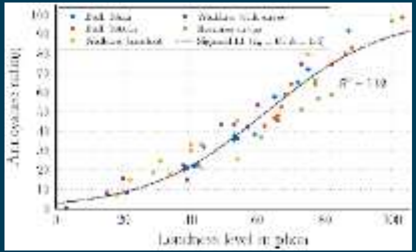
Consistent rating according to total loudness

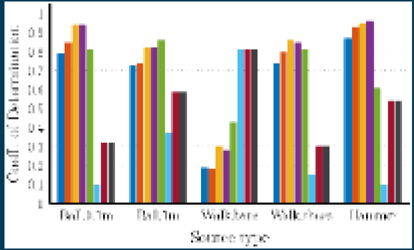
Good agreement between online vs laboratory

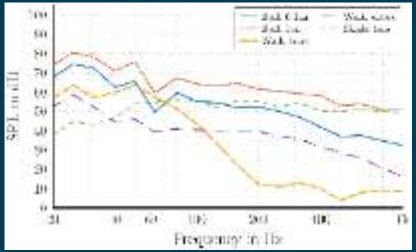
High correlation with standard metrics for most sources

Low-frequency metrics important for barefoot walking

What to do with this information?







Proposed NBC changes for impact sound

Change objective OH3 to include impact sound
(currently only airborne sound)

Add impact sound requirements to Part 5 and Part 9 of NBC

- Requirement of
  - minimum AIIC 47, or
  - Minimum IIC 50 + adjoining construction details from Part 9

Proposed NBC changes for impact sound

Three paths for demonstrating compliance

1. Post completion field testing (ASTM E1007)

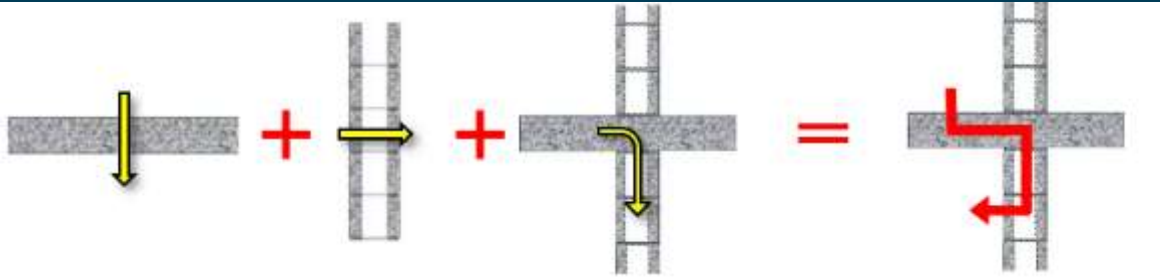
2. Prescriptive procedure (Part 9), based on ASTM E492 lab data (IIC) plus new details for specific types of construction

3. Detailed design procedure (Part 5), which uses the calculation method following ISO 12354-2
   → RR-332

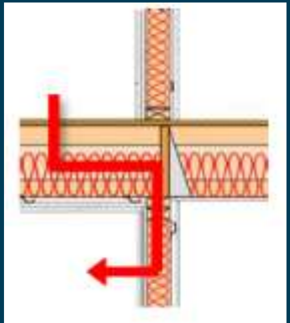
Detailed design procedure (Part 5)

The AIIC rating is calculated using the method described in ISO 12354-2

Heavy, homogeneous construction

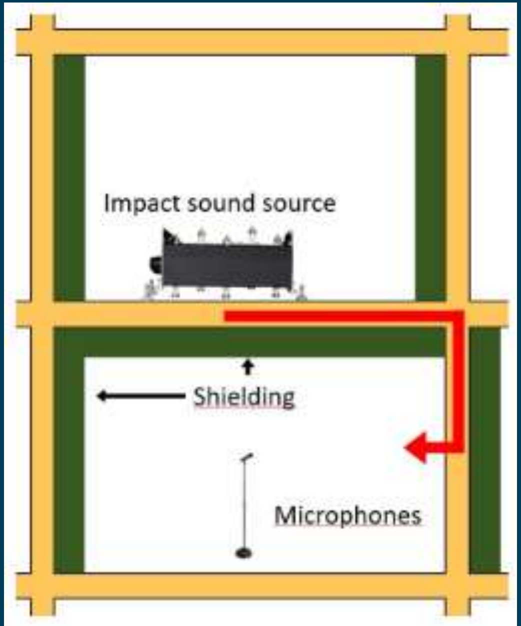


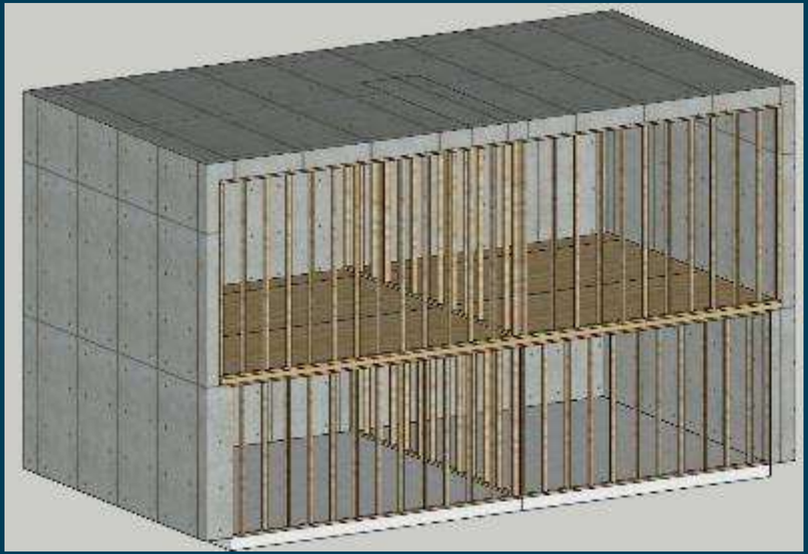
Light-frame construction



Detailed design procedure (Part 5)

Flanking measurements for light-frame and hybrid construction





Detailed design procedure (Part 5)

Described in RR-332

- ISO 12354-2 methodology
- Converted to ASTM metrics
  (ISO metric lower for better performance)

Research Report RR-332

Special Interest Group on Impact Sound

AcoustiTECH

CCMPA
CANADIAN CONCRETE MASONRY PRODUCERS' ASSOCIATION

CPCI.ca

Canadian Wood Council
Conseil canadien du bois

MAXXON

OWENS CORNING

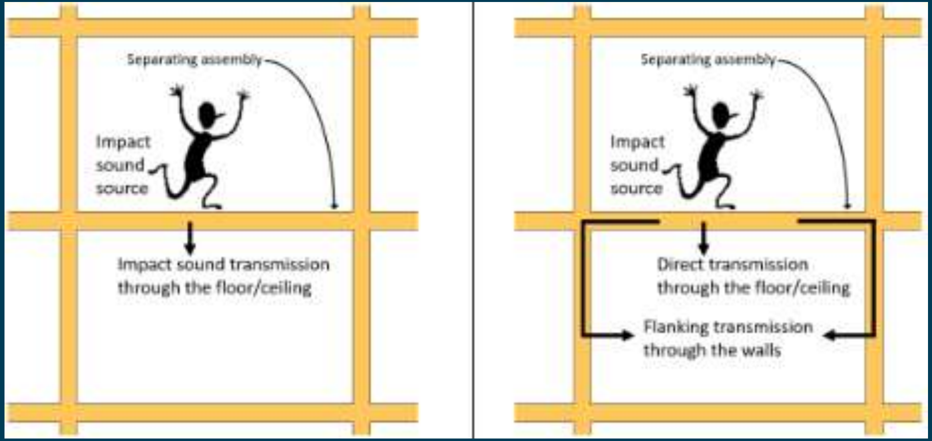
PLITEQ

ROCKWOOL

SOPREMA

Research Report RR-332

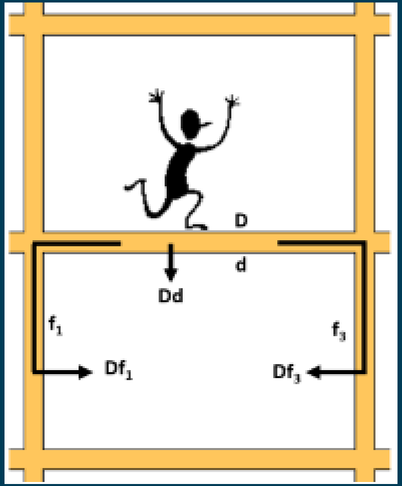
- Explains the AIIC rating
- Presents the equations used for the calculations
- Explains how to calculate improvements due to toppings or linings
- Step by step instructions to calculate the AIIC rating for different construction types



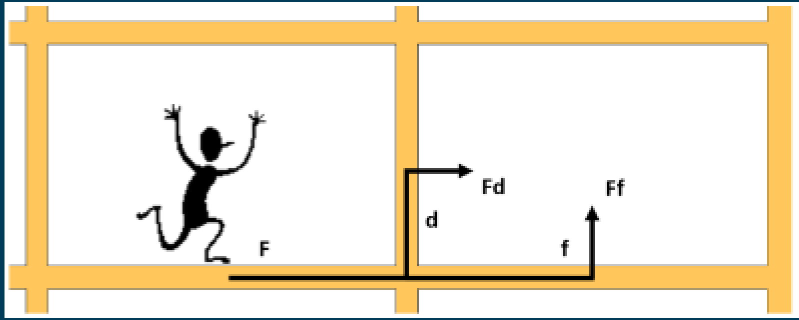
Research Report RR-332

Transmission paths for impact sound

Vertical: 1 direct + 4 flanking



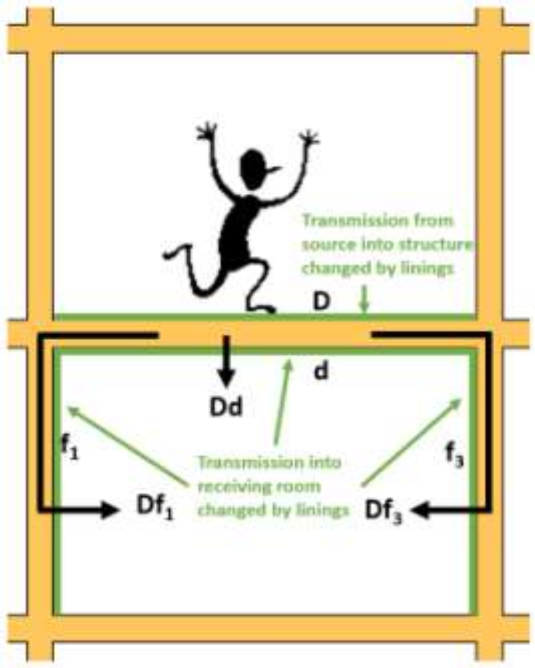
Horizontal: 0 direct + 2 flanking



Research Report RR-332

Improvement due to linings (concrete and mass timber)

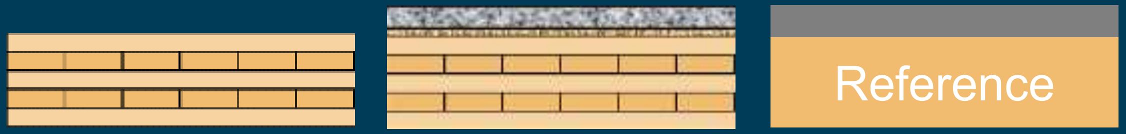
- Impact data for direct floor-ceiling path
- Impact and airborne data for floor-wall and floor-floor flanking paths
- ASTM E2179 (ΔIIC) for concrete
- New reference curves for mass timber (ISO 717-2)



Research Report RR-332

Improvement due to linings

$NISPL_1$ **$NISPL_2$** **$\Delta NISPL$**



→ **ΔIIC**

Airborne → RR-331 and RR-335

EXAMPLE 2.6.3: SIMPLIFIED METHOD

- Rooms side-by-side
- Loadbearing normal weight hollow concrete block masonry walls and concrete floors with rigid junctions
- Same structure and lining as Example 2.4.2

Separating wall element (loadbearing):

- One wythe of 190 mm thick concrete block masonry[1] constructed from normal weight units not less than 53% solid with a mass per unit area of 238 kg/m².
- Lining of 12.7 mm fire rated gypsum board on 65 mm steel studs spaced 610 mm on center with an air gap of 12.7 mm and 65 mm of absorptive material[4] between the studs RR-334 ΔTL-BLK(NW)-62.

Junction 1: Rigid mortared cross junction between the separating wall and the floor:

- Normal weight 200 mm thick concrete floor with a mass per unit area of 467 kg/m² with no lining on the floor or ceiling.

Junction 2 or 4: Rigid mortared T-junction between separating wall and abutting side walls:

- Abutting side walls each of one wythe of 190 mm thick concrete block masonry[1] constructed from normal weight units not less than 53% solid with a mass per unit area of 238 kg/m².
- Lining of 12.7 mm fire rated gypsum board on 65 mm steel studs spaced 610 mm on center with an air gap of 12.7 mm and 65 mm of absorptive material[4] between the studs RR-334 ΔTL-BLK(NW)-62.

Junction 3: Rigid mortared cross junction between the separating wall and the ceiling.

- Normal weight 200 mm thick concrete floor / ceiling with a mass per unit area of 467 kg/m² with no lining on the floor or ceiling.

Acoustical Parameters:

For the 190 mm Concrete Block Masonry Wall:

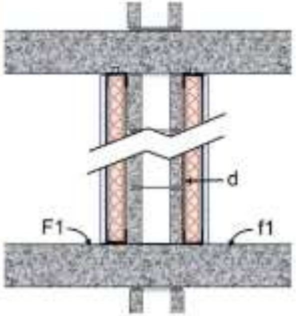
Mass/unit area (kg/m²) = 238 (Separating wall)
238 (Flanking wall)

For the 200 mm Concrete Floor:

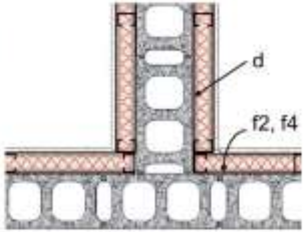
Mass/unit area (kg/m²) = 467

Floor area (m²) = 20
Floor/wall junction length (m) = 5.0
Separating partition height (m) = 2.5
10*log(S_floor/l_junction 1&3) = 6.0
10*log(S_floor/l_junction 2&4) = 9.0

Illustration for this case



Rigid mortared cross-junction between the 190 mm thick concrete block masonry separating walls with linings and the 200 mm thick concrete floor and ceiling. (Side view of Junctions 1 or 3)



Rigid mortared T-junction between walls with linings, both of 190 mm thick concrete block masonry constructed using normal weight units not less than 53% solid and with mass per unit area of 238 kg/m². (Plan view of Junction 2 or 4)

Junction		M	$\overline{K_{ij}}$ (dB) Path Ff	Path Fd	Path Df	Reference
1	Rigid-Cross junction	-0.29	4.2	9.2	-	ISO 12354-1, Fig. E.1
2	[illegible]	[illegible]	[illegible]			[illegible]
3	Rigid-Cross junction	0.29	9.2			ISO 12354-1, Fig. E.1
4	Rigid-Cross junction	0.29	9.2			ISO 12354-1, Fig. E.1

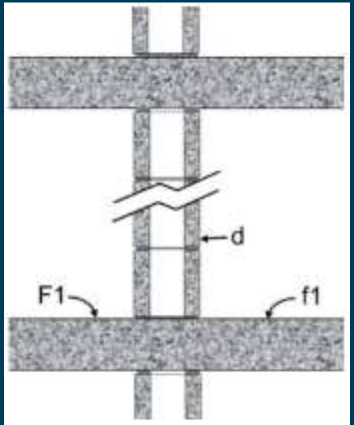
	Symbol	Reference		STC, IIC, ΔSTC or ΔIIC	IIC or AIIC
Separating Wall Partition					
Laboratory STC for d	STC_d	RR-334, BLK190(NW)		45	
ΔSTC change by Lining on d	ΔSTC_d	RR-334, ΔTL-BLK(NW)-62, AIR13_SS65(610)_GFB65_G13		19	
		Direct path not relevant for impact sound transmission			
Junction 1: Junction between the floor and the separating wall					
Flanking Element F1:					
Laboratory IIC for F1	IIC_F	RR-332, CON200		30	
ΔIIC change by Lining	ΔIIC_F	No lining		0	
Flanking Element f1:					
Laboratory STC for f1	STC_f	RR-334, CON200		60	
ΔSTC change by Lining	ΔSTC_f	No lining		0	
Flanking IIC for path Ff	IIC_{Ff}	RR-332 Equation 2.8	30 + 60/2 - 60/2 + MAX(0,0) + MIN(0,0)/2 + 4.2 + 6 =		**40**
Flanking IIC for path Fd	IIC_{Fd}	RR-332 Equation 2.8	30 + 49/2 - 60/2 + MAX(0,19) + MIN(0,19)/2 + 9.2 + 6 =		**59**
Flanking IIC for Junction 1		RR-332 Equation 1.4	- 10*LOG10(10^-4.02 + 10^-5.87) =		**40**

Junction 2: Junction between the separating wall and the abutting façade wall
Junction 3: Junction between the separating wall and the ceiling
Junction 4: Junction between the separating wall and the abutting corridor wall

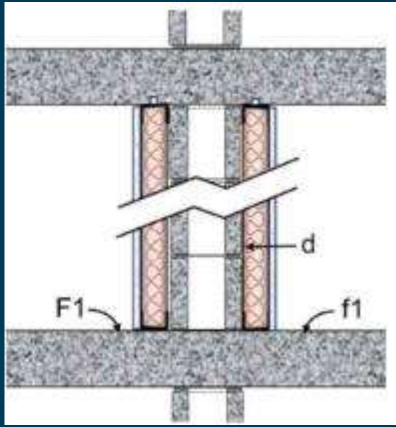
No flanking contribution for impact sound transmission

Total Flanking IIC for All of the Junctions	Flanking IIC value from Junction 1	**40**
AIIC Rating	Flanking IIC value from Junction 1	**40**

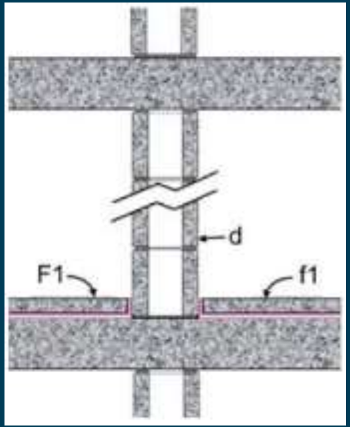
Examples: 200 mm concrete (horizontal)



Combined
AIIC
37

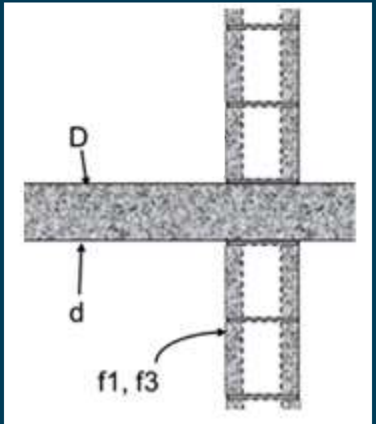


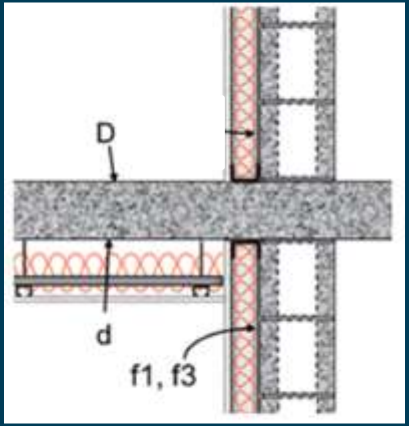
Combined
AIIC
40

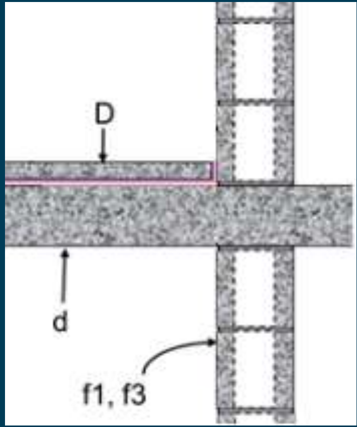


	Combined
	AIIC
	63
Detailed method:	63

Examples: 200 mm concrete (vertical)

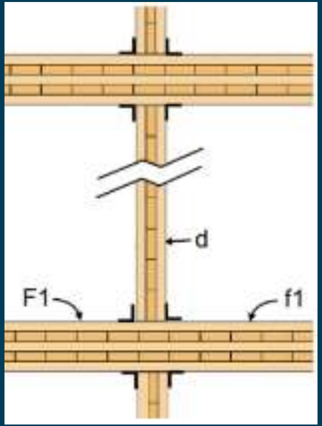




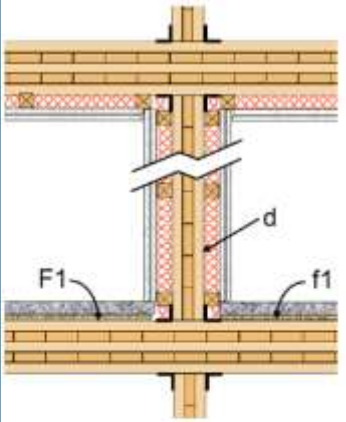


Direct	Flanking	Combined	Direct	Flanking	Combined	Direct	Flanking	Combined
IIC	IIC	AIIC	IIC	IIC	AIIC	IIC	IIC	AIIC
30	33	28	54	52	50	55	58	53
					Detailed method:	58	62	56

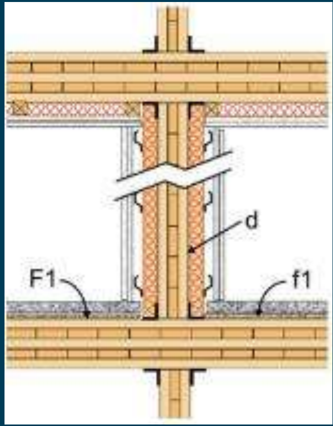
Examples: 5-ply CLT, 175 mm (horizontal)



Combined
AIIC
31



Combined
AIIC
46

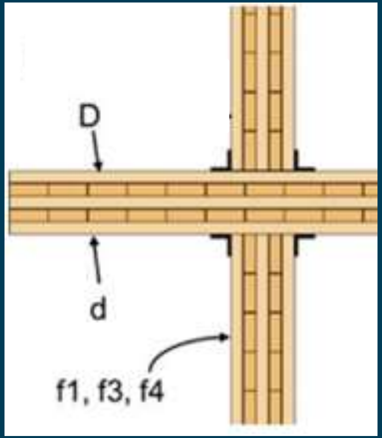


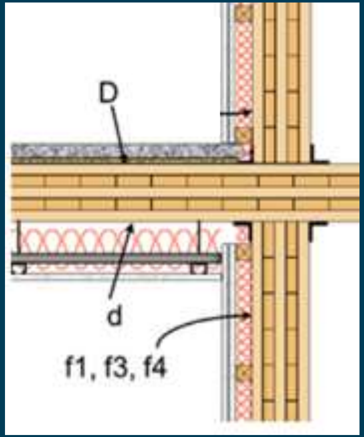
Combined
AIIC
47

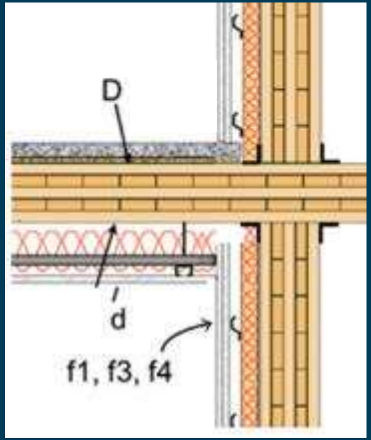
Detailed method:

58

Examples: 5-ply CLT, 175 mm (vertical)

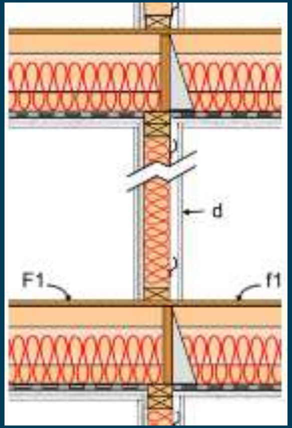




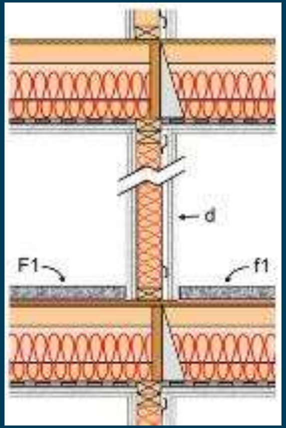


	Direct	Flanking	Combined	Direct	Flanking	Combined	Direct	Flanking	Combined
	IIC	IIC	AIIC	IIC	IIC	AIIC	IIC	IIC	AIIC
	25	35	25	60	49	48	60	55	54
Detailed method:							62	61	59

Examples: 305 mm wood I-joists (horizontal)

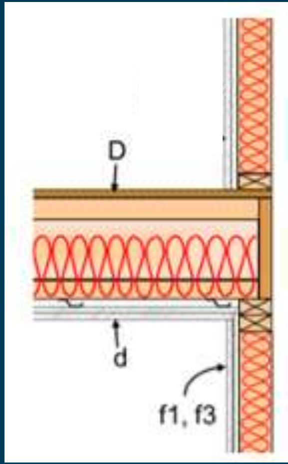


Combined
AIIC
33

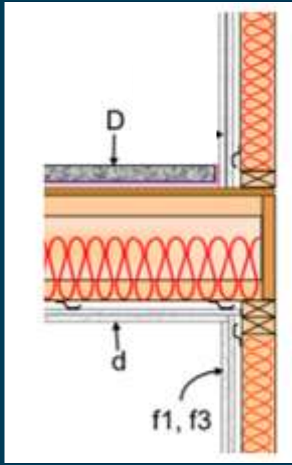


Combined
AIIC
52

Examples: 305 mm wood I-joists (vertical)



Direct	Flanking	Combined
IIC	IIC	AIIC
44	45	41

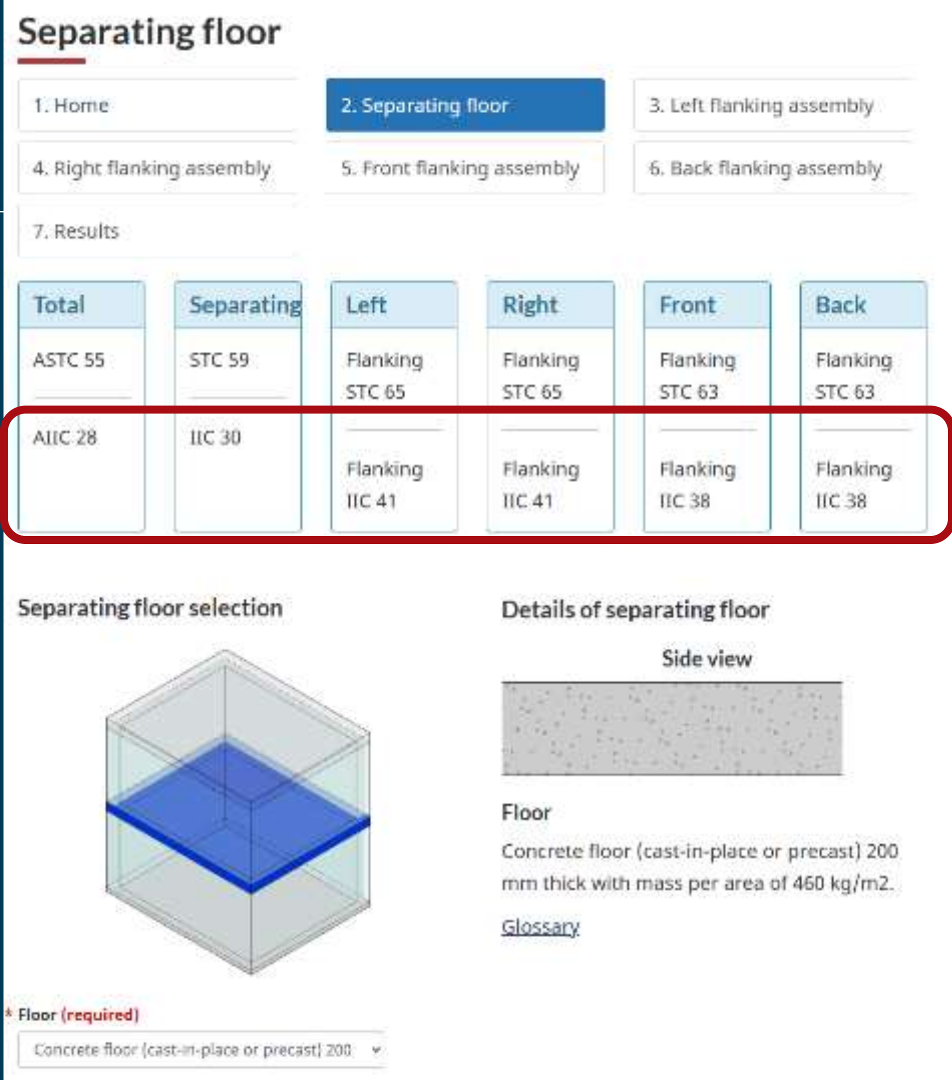


Direct	Flanking	Combined
IIC	IIC	AIIC
55	≥53	≥51

soundPATHS

Updated to include

- (A)IIC calculation
- Laboratory data



Conclusion – AIIC

Impact noise not (yet) addressed in NBC

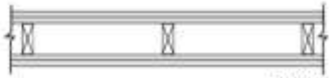
SIG Impact Sound is

- Raising awareness
- Collecting data
- Developing design tools (RR-332, soundPATHS)

Ongoing work at the NRC

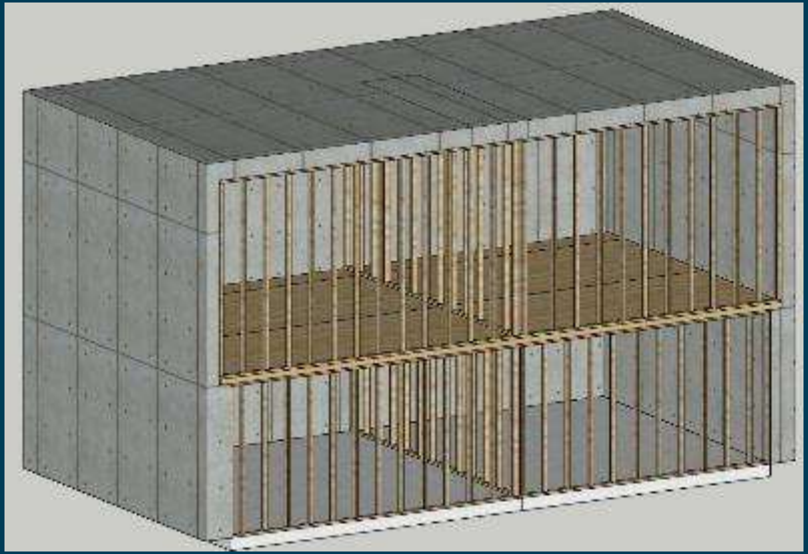
The NRC is measuring the transmission loss of the wall assemblies in Part 9 of the NBCC

- Updates to Part 9 tables + RR-336
- Data to be included in soundPATHS

Wall Number	Description	Fire-Resistance Rating [2] [3]		Typical Sound Transmission Class [2] [4] [5]
		Loadbearing	Non-Loadbearing	
W2	• 38 mm x 89 mm studs spaced 400 mm or 600 mm o.c. • with or without absorptive material • 2 layers of gypsum board on each side	 GC00003A		
W2a	W2 with • 89 mm thick absorptive material [6] • 15.9 mm Type X gypsum board [7]	1.5 h	2 h	38
W2b	W2 with • 89 mm thick absorptive material [6] • 12.7 mm Type X gypsum board [7]	1 h	1.5 h	38
W2c	W2 with • 89 mm thick absorptive material [6] • 12.7 mm regular gypsum board [7]	45 min	1 h	36
W2d	W2 with • no absorptive material • 15.9 mm Type X gypsum board [7]	1.5 h	2 h	36
W2e	W2 with • no absorptive material • 12.7 mm Type X gypsum board [7]	1 h	1.5 h	35

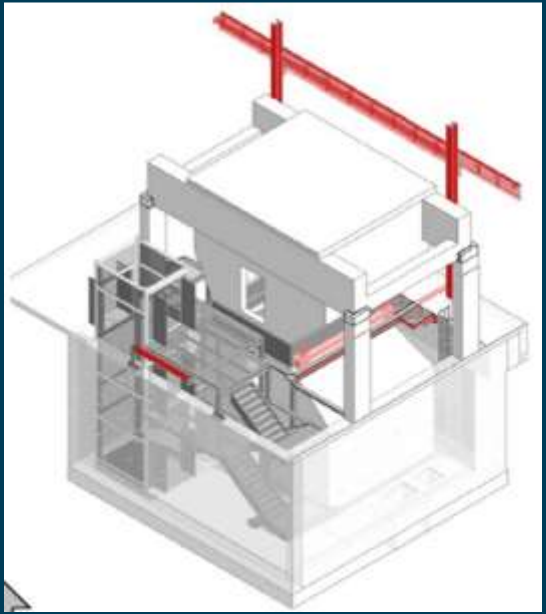
Ongoing work at the NRC

Research on mass timber, especially hybrid construction
(mass timber floors + light-frame walls)

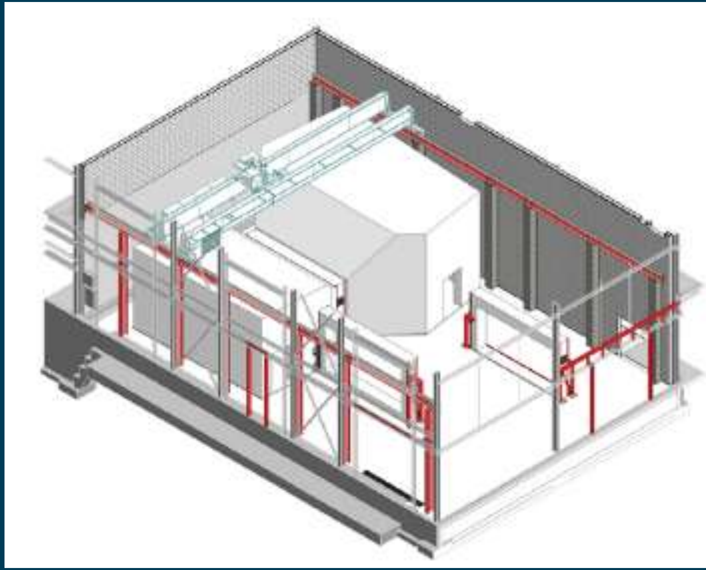


New floor and wall facilities

Floor testing facility

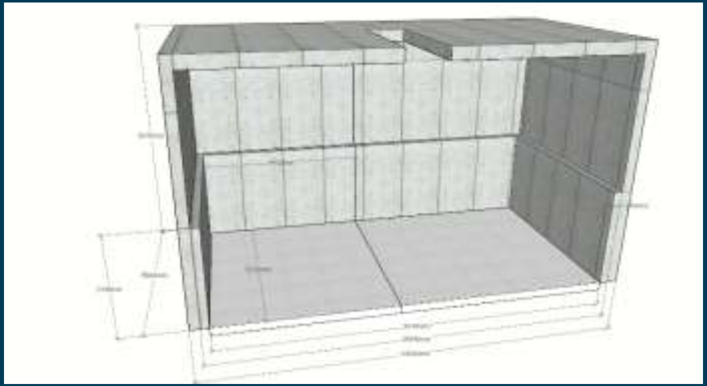


Wall testing facility

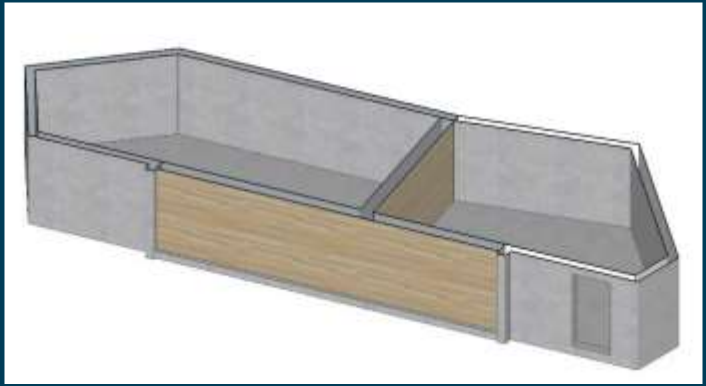


New flanking facilities

Four-room flanking facility



Two-room flanking facility



Summary

In partnership with industry, the NRC has developed a number of tools to help with the calculation of the ASTC and AIIC rating

- RR-331 and RR-332
- Research publications
- ASTC calculation workshops (AIIC in the future)
- soundPATHS