ACOUSTIC CLASSES CALCULATION FOR VIRTUAL BUILDING

Final report

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1 - DESCRIPTION OF WORK

1.1 - Context

Numerous subsidies are available in European countries to support thermal insulation as part of energy-saving initiatives. Concurrently, acoustic comfort has become a significant concern for both end-users and policymakers. A recent French study revealed that the social cost of noise in France alone is estimated at 147 billion euros annually, with one-third directly linked to building acoustic insulation. Mineral wool is recognized, in academic community, as the material that best balances thermal and acoustic insulation. However, for end users, acoustic comfort is more challenging to quantify than energy savings or thermal comfort. While most countries have established thermal and energy classifications, few European countries possess an equivalent for acoustics.

Some European countries have adopted an acoustic classification system. However, the principles and application of these classifications vary greatly from one country to another.

A Technical Specification has been adopted at the ISO level to guide the harmonization of European acoustic classes. ISO TS 19488 provides a methodology for assessing acoustic classes in buildings, but its drafting revealed some issues or challenges, including data gaps and limited perspective on class calculations and the implementation systems required. Another significant obstacle in achieving consensus was the issue of low frequencies indicator for evaluating the highest classes.

1.2 - Objectives

This study has two main goals:

- to provide data based on the use of mineral wool for the calculation of harmonised acoustic classes (ISO TS 19488), with a focus on sound insulation between rooms in both old and new buildings;
- to examine the effects of the new SNQ, proposed in a joint study by CSTB and KU Leuven[1], which includes low frequencies in the evaluation of acoustic classes.

The objective is to select two typical old buildings with poor acoustic performance and to "virtually" renovate them to achieve two distinct levels of acoustic performance, using calculation

[1] https://journals.sagepub.com/doi/full/10.1177/1351010X241236402
https://acta-acustica.edpsciences.org/articles/aacus/full_html/2023/01/aacus220074/aacus220074.html

methodologies based on the ISO 12354 series. Similarly, two modern buildings (one constructed from concrete and the other from wood – construction types will be extracted from ISO 12354 series) will be used to establish two levels of acoustic classification: the basic level, as defined by current regulations, and the highest achievable level.

The study will focus exclusively on airborne sound insulation between rooms (from one flat to another), considering both vertical and horizontal configurations (i.e. direct transmission through a separating wall and trough a floor).
Performance level for the different building configurations will be evaluated in one-third octave bands between 50 and 5000 Hz, allowing to calculate different SNQs.

For each step, the conventional ISO TS 19488 will be employed to calculate the acoustic class of these buildings for their different configurations. Additionally, classes will also be investigated using new SNQs.

1.3 - Task 1

The aim of Task 1 is to define the buildings under investigation. Two different old building types and two typical buildings corresponding to new constructions have therefore been selected:

- Typical apartment from the 1930s (stone and wood)
- Typical apartment from the 1970s (concrete and brick)
- Concrete construction
- Wood construction

Along with the buildings, a renovation or upgraded acoustic solution based on the use of mineral wool has to be proposed for each building type to achieve two higher thermal and acoustic classes than the original one. Note that no thermal calculations are planned.

1.4 - Task 2

The goal of Task 2 is the acoustic performance evaluation for different building configurations.
The building performance with respect to airborne sound insulation will be performed using the AcouBat software (based on the EN ISO 12354 standard series) between the one-third octave bands 50 to 5000 Hz.
Once the one-third octave band airborne sound insulation between flats (in the horizontal and vertical direction) is obtained, SNQs are evaluated based on ISO 717-1 and on the work from CSTB and KU Leuven[1]. Then, the performance classes based on ISO TS 19488 is deduced.

Loudness is also assessed using representative indoor acoustic environment spectra based on previous CSTB work[1,2].

The class performance based on the Qualitel system[3] is also calculated for comparison.

The analysis of the results for the buildings under investigation before and after renovation or upgraded regarding their acoustic situation, completes this task.

A meeting with Eurima on March 24th 2025 allowed a discussion on the obtained results.

1.5 - Task 3

The last task concerns the final report of this study including detailed results and results analysis following Task 2 discussion.

[2] C. Guigou Carter, J. Maillard, S. Bailhache, Possible representative indoor acoustic environment spectra, Forum Acusticum 2023. https://dael.euracoustics.org/confs/fa2023/data/articles/000100.pdf

[3] N. Balanant, C. Guigou Carter, Grading system for dwellings acoustic performance implemented in French housing quality certification, Forum Acusticum 2023. https://dael.euracoustics.org/confs/fa2023/data/articles/000099.pdf .

2 - TASK 1 – BUILDING TYPES

A meeting with Eurima on January 17th 2025 allowed to discuss and fixed the buildings composition and configuration under investigation presented in this section.

2.1 - Building from the 1930s

The building composition corresponding to the selected period is given in Table 2.1.1.

Table 2.1.1: Building from the 1930s

Building element	Description	SNQ
Façade	- Stone grit 45 cm at ground floor - Solid bricks 22 cm (up to 33 cm) at floors above ground floor	R_w+C = 43 dB R_w+$C_{50\text{-}3150}$ = 43 dB
Load-bearing wall	Solid bricks 33 cm	-
Separating wall	Solid bricks 22 cm	R_w+C = 43 dB R_w+$C_{50\text{-}3150}$ = 43 dB
Partition	Bricks or clinker blocks 5 cm	R_w+C = 29 dB R_w+$C_{50\text{-}3150}$ = 29 dB
Floor	Floor (250 mm) with metallic joists with plaster elements and sand filling, and wood finish 22 mm	R_w+C = 53 dB R_w+$C_{50\text{-}3150}$ = 52 dB
Ceiling	Plaster 2 cm	-
Floor covering	-	-

The proposed basic renovation solution is based on the following elements:

- Façade: lining composed of mineral wool 100 mm with a single layer of 12.5 mm thick plaster boards on independent frame;
- Suspended ceiling: 100 mm with 80 mm of mineral wool with a single layer of 12.5 mm thick plaster boards;
- Separating wall: lining composed of 45 mm of mineral wool with a single layer of 12.5 mm thick plaster boards on independent frame.

Renovation solution will be adapted as function of acoustic performance (mineral wool thickness within reasonable range).

The lining on the façade will be implemented if necessary (as a function of the associated flanking paths acoustic performance).

2.2 - Building from the 1970s

The building composition corresponding to the selected period is given in Table 2.2.1.

Table 2.2.1: Building from the 1970s

Building element	Description	SNQ
Façade	Concrete 20 cm	R_w+C = 62 dB $R_w+C_{50-3150}$ = 62 dB
Load-bearing wall	Solid bricks 33 cm	-
Separating wall	- Hollow bricks 30 cm - Concrete 15 cm	R_w+C = 44 dB $R_w+C_{50-3150}$ = 44 dB R_w+C = 55 dB $R_w+C_{50-3150}$ = 55 dB
Partition	Bricks 5 cm	R_w+C = 29 dB $R_w+C_{50-3150}$ = 29 dB
Floor	Concrete 16 cm	R_w+C = 57 dB $R_w+C_{50-3150}$ = 57 dB
Ceiling	-	-
Floor covering	Wood flooring or carpet (on a 4 cm screed)	-

The proposed basic renovation solution is based on the following elements:

- Façade: lining composed of mineral wool 100 mm with a single layer of 12.5 mm thick plaster boards on independent frame;
- Plastic floor covering $\Delta L_w \geq 19$ dB;
- Suspended ceiling 45 mm of mineral wool with a single layer of 12.5 mm thick plaster boards;
- Separating wall: lining composed of 45 mm of mineral wool with with a single layer of 12.5 mm thick plaster boards on independent frame.

Renovation solution will be adapted as function of acoustic performance (mineral wool thickness within reasonable range).

The lining on the façade will be implemented if necessary (as a function of the associated flanking paths acoustic performance).

2.3 - Modern concrete-based building

The composition of the concrete based building is given in Table 2.3.1.

Table 2.3.1: Modern concrete-based building.

Building element	Description	SNQ
Façade	Concrete 16 cm with lining $\Delta(R_w + C)_{heavy\ wall} \geq 3$ dB	$R_w+C = 57$ dB $R_w+C_{50\text{-}3150} = 57$ dB
Load-bearing wall	Concrete 18 cm	-
Separating wall	Concrete 18 cm	$R_w+C = 60$ dB $R_w+C_{50\text{-}3150} = 60$ dB
Partition	Monobloc lightweight panels (plasters boards sandwiching a honeycomb cardboard) 5 cm	$R_w+C = 26$ dB $R_w+C_{50\text{-}3150} = 26$ dB
Floor	Concrete 19 cm	$R_w+C = 61$ dB $R_w+C_{50\text{-}3150} = 61$ dB
Ceiling	-	-
Floor covering	Plastic floor covering $\Delta L_w \geq 19$ dB	-

The proposed upgrading solution is based on the following elements:

- Façade: lining composed of mineral wool 100 mm with a single layer of 12.5 mm thick plaster boards on independent frame;
- Floating screed on mineral wool $\Delta L_w \geq 20$ dB and $\Delta(R_w + C)_{heavy\ floorl} \geq 3$ dB;
- Separating wall: lining composed of mineral wool 45 mm with a single layer of 12.5 mm thick plaster boards on independent frame.

The solution will be upgraded as function of acoustic performance (mineral wool thickness within reasonable range).

The lining on the façade will be implemented if necessary (as a function of the associated flanking paths acoustic performance).

2.4 - Modern wood-based building

The composition of the wood-based building is given in Table 2.4.1.

Table 2.4.1: Modern wood-based building.

Building element	Description	SNQ
Façade	Lightweight wood frame wall (145 mm posts with braced 12 mm OSB board on the outside with mineral wool between posts, and lining on the interior side with an independent interior lining composed of with a double layer of 12.5 mm thick plaster boards on an independent metal frame with 45 mm mineral wool	R_w+C = 55 dB $R_w+C_{50-3150}$ = 54 dB
Load-bearing wall	-	-
Separating wall	CLT 94 mm in thickness with lining on both side made of mineral wool 45 mm with a single layer of 12.5 mm thick plaster boards on independent frame	R_w+C = 34 dB $R_w+C_{50-3150}$ = 34 dB $\Delta(R_w+C)$ = 14 dB $\Delta(R_w+C_{50-3150})$ = 14 dB
Partition	Monobloc lightweight panels (plasters boards sandwiching a honeycomb cardboard) 5 cm	R_w+C = 26 dB $R_w+C_{50-3150}$ = 26 dB
Floor	CLT 140 mm	R_w+C = 35 dB $R_w+C_{50-3150}$ = 35 dB
Ceiling	Suspended ceiling – Cavity 100 mm with 80 mm of mineral wool and 2 layers 13 mm thick plaster boards	$\Delta(R_w+C)$ = 18 dB $\Delta(R_w +C_{50-3150})$ = 17 dB
Floor covering	Floating screed (5 cm) on thin resilient layer (3 mm)	$\Delta(R_w+C)$ = 12 dB $\Delta(R_w+C_{50-3150})$ = 12 dB

The proposed basic renovation solution is based on the following elements:

- Façade: lining replacement, mineral wool 100 mm with a single layer of 12.5 mm thick plaster boards on independent frame;
- Separating wall: lining with 100 mm of mineral wool;
- Floating screed on mineral wool $\Delta L_w \geq 20$ dB and $\Delta(R_w+C)_{heavy\ floorl} \geq 3$ dB
- Suspended ceiling: increase thickness of mineral wool then add plaster board layer

The solution will be upgraded as function of acoustic performance (mineral wool thickness within reasonable range).

The lining on the façade will be implemented if necessary (as a function of the associated flanking paths acoustic performance).

2.5 - Building geometry

For simplicity, the same building configuration will be applied to the 4 different types of buildings presented in Sections 2.1 to 2.4. The considered configuration is shown in Figure 2.5.1. It is composed of 4 rooms distributed on two levels with

- 2 superposed living rooms of dimensions 4,2 m x 6 m = 25,2 m²;
- 2 superposed bedrooms of dimensions 3.2 m x 2.8 m = 9 m².

The floor to ceiling height is

- 3.0 m for the 1930s building;
- 2.7 m for the 1970 building;
- 2.5 m for the nowadays buildings.

Airborne sound insulation (vertical and horizontal directions) between living spaces of four different dwellings has to be evaluated. Therefore, excluded from the investigation is the airborne sound insulation with respect to outdoor, with respect to hallway/circulations and other room types such as activities rooms, collective spaces, parking garages, etc….

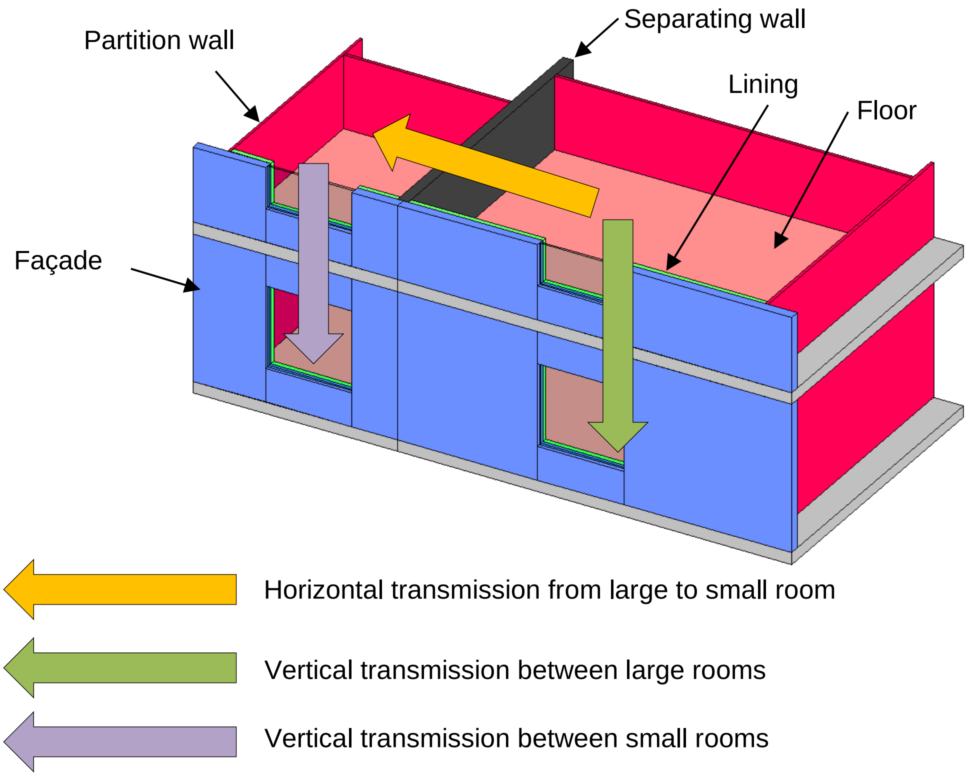


Figure 2.5.1: Building configuration.

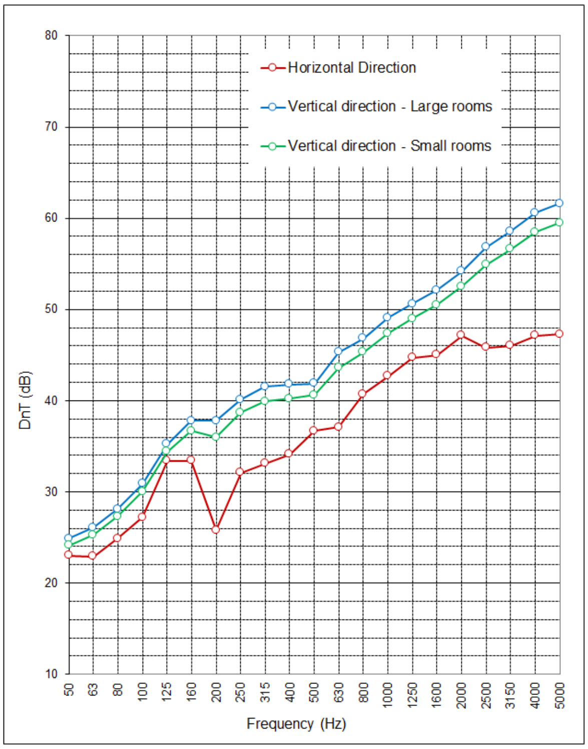
3 - TASK 2 – AIRBORNE SOUND INSULATION FOR BUILIDNGS IN ORIGINAL CONFIGURATION

The results of the acoustic performance evaluation are presented in this section for the different building types before any renovation or upgrade with respect to their acoustic situation.

Note that the horizontal airborne sound insulation is evaluated using the small room as reception room.

3.1 - Building from the 1930s

Figure 3.1.1 presents the airborne sound insulation obtained to the horizontal and vertical direction for the 1930s building.



	Horizontal Direction	Vertical direction - Large rooms	Vertical direction - Small rooms
Frequency (Hz)	D_{nT} (dB)	D_{nT} (dB)	D_{nT} (dB)
50	23.0	24.9	24.1
63	22.9	26.1	25.3
80	24.9	28.1	27.3
100	27.2	30.9	30.0
125	33.4	35.2	34.4
160	33.4	37.8	36.7
200	25.8	37.8	36.0
250	32.1	40.1	38.7
315	33.1	41.5	39.9
400	34.1	41.8	40.2
500	36.7	41.9	40.6
630	37.1	45.3	43.6
800	40.7	46.8	45.3
1000	42.7	49.1	47.4
1250	44.7	50.6	49.0
1600	45.0	52.1	50.5
2000	47.1	54.2	52.5
2500	45.8	56.8	54.9
3150	46.0	58.6	56.6
4000	47.1	60.6	58.5
5000	47.3	61.6	59.5

$D_{nT,w}$ =	41	48	47
C =	-1	-1	-1
C_{tr} =	-4	-4	-4
$C_{(50-3150)}$ =	-2	-1	-2
$C_{tr(50-3150)}$ =	-6	-7	-7

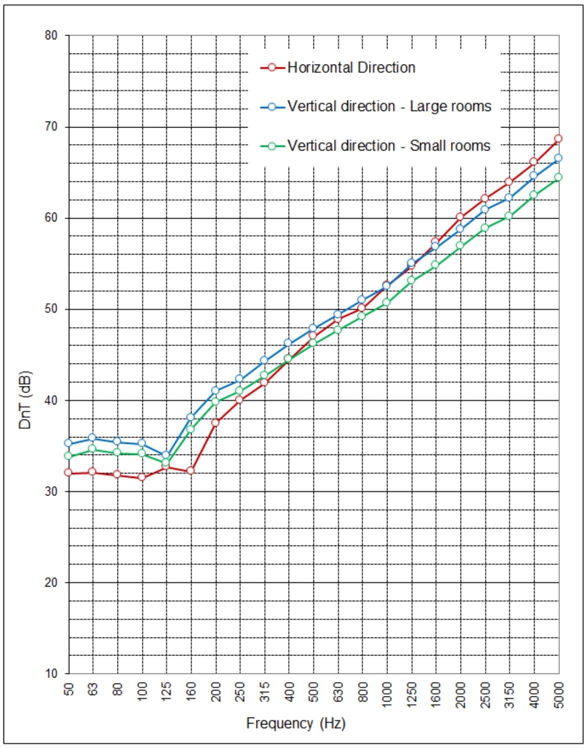
$D_{nT,w}$ + C =	40	47	46
$D_{nT,w}$ + C_{50} =	39	47	45

$D_{nT,w}$ + C_{I40} =	41	49	48
$D_{nT,w}$ + $C_{IndoorA}$ =	42	49	48
$D_{nT,w}$ + $C_{Indoor40}$ =	42	50	49

Figure 3.1.1: Airborne sound insulation for the 1930s building.

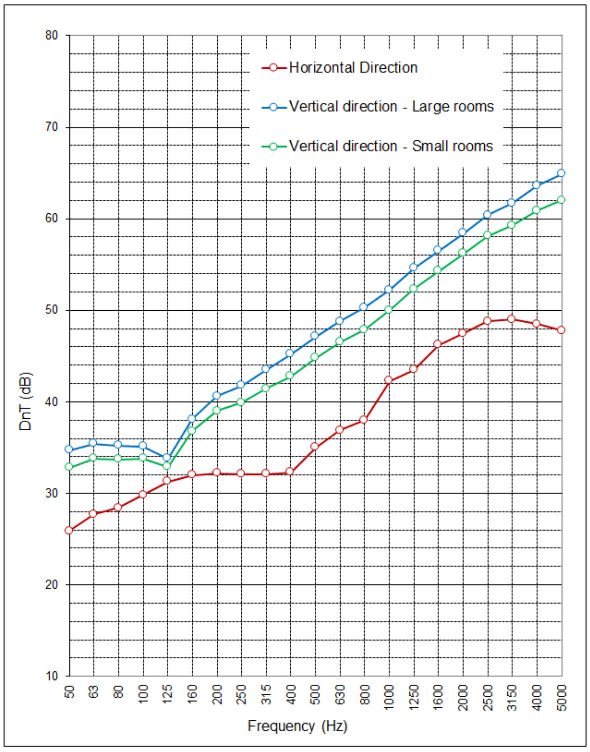
3.2 - Building from the 1970s

Figure 3.2.1 and Figure 3.2.2 present the airborne sound insulation obtained to the horizontal and vertical direction for the 1970s building in the case of a concrete separating wall and a hollow bricks separating wall respectively.



	Horizontal Direction	Vertical direction - Large rooms	Vertical direction - Small rooms
Frequency (Hz)	D_{nT} (dB)	D_{nT} (dB)	D_{nT} (dB)
50	32.0	35.2	33.8
63	32.1	35.8	34.6
80	31.8	35.4	34.2
100	31.5	35.2	34.1
125	32.7	33.9	33.1
160	32.2	38.1	36.8
200	37.5	41.0	39.8
250	40.0	42.3	41.0
315	41.9	44.3	42.7
400	44.5	46.2	44.5
500	47.0	47.9	46.2
630	48.9	49.4	47.7
800	50.1	51.0	49.2
1000	52.6	52.5	50.7
1250	54.7	55.0	53.1
1600	57.3	56.8	54.8
2000	60.1	58.8	56.9
2500	62.1	60.9	58.9
3150	63.9	62.2	60.2
4000	66.1	64.6	62.5
5000	68.6	66.5	64.4
$D_{nT,w}$ =	50	52	50
C =	-2	-1	-1
C_{tr} =	-6	-5	-4
$C_{(50-3150)}$ =	-2	-2	-1
$C_{tr(50-3150)}$ =	-7	-6	-5
$D_{nT,w}$ + C =	48	51	49
$D_{nT,w}$ + C_{50} =	48	50	49
$D_{nT,w}$ + C_{I40} =	51	53	51
$D_{nT,w}$ + $C_{IndoorA}$ =	52	53	52
$D_{nT,w}$ + $C_{Indoor40}$ =	53	54	53

Figure 3.2.1: Airborne sound insulation for the 1970s building for concrete separating wall.

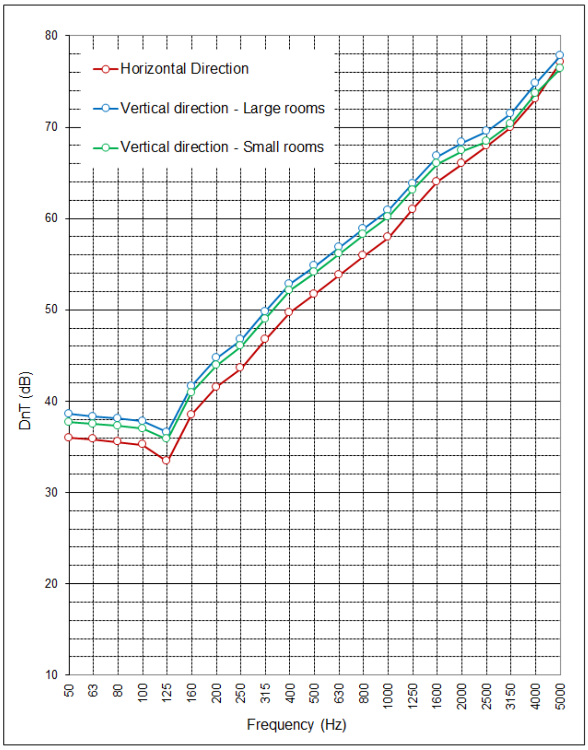


	Horizontal Direction	Vertical direction - Large rooms	Vertical direction - Small rooms
Frequency (Hz)	D_{nT} (dB)	D_{nT} (dB)	D_{nT} (dB)
50	25.9	34.7	32.8
63	27.7	35.4	33.8
80	28.4	35.2	33.7
100	29.8	35.1	33.8
125	31.3	33.8	32.9
160	32.0	38.1	36.8
200	32.2	40.6	39.0
250	32.1	41.8	39.9
315	32.1	43.5	41.4
400	32.3	45.2	42.8
500	35.0	47.1	44.8
630	36.9	48.8	46.5
800	38.0	50.3	47.9
1000	42.3	52.2	50.0
1250	43.5	54.6	52.3
1600	46.2	56.5	54.3
2000	47.5	58.4	56.2
2500	48.8	60.4	58.1
3150	49.0	61.7	59.3
4000	48.5	63.6	60.9
5000	47.8	64.9	62.0
$D_{nT,w}$ =	40	51	49
C =	0	-1	-1
C_{tr} =	-3	-5	-4
$C_{(50-3150)}$ =	-1	-1	-1
$C_{tr(50-3150)}$ =	-3	-5	-5
$D_{nT,w}$ + C =	40	50	48
$D_{nT,w}$ + C_{50} =	39	50	48
$D_{nT,w}$ + C_{I40} =	41	53	50
$D_{nT,w}$ + $C_{IndoorA}$ =	41	53	51
$D_{nT,w}$ + $C_{Indoor40}$ =	42	54	51

Figure 3.2.2: Airborne sound insulation for the 1970s building for brick-based separating wall.

3.3 - Modern concrete-based building

Figure 3.3.1 presents the airborne sound insulation obtained to the horizontal and vertical direction for the modern concrete-based building.

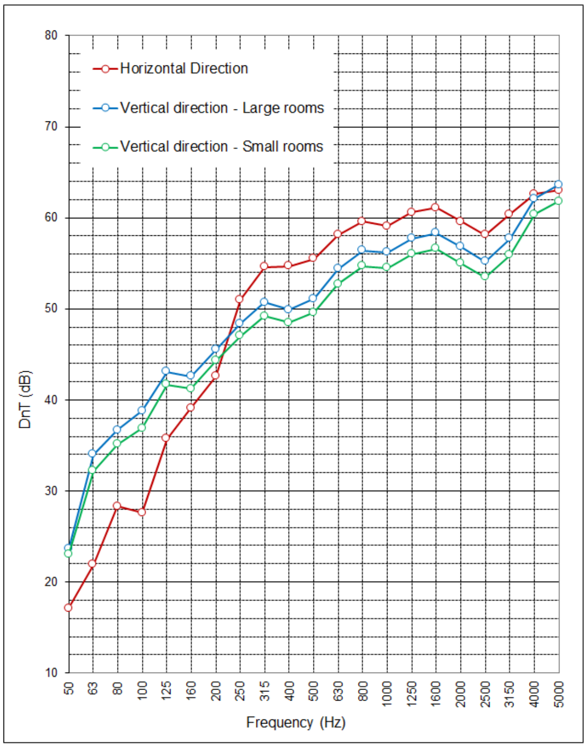


Frequency (Hz)	Horizontal Direction D_{nT} (dB)	Vertical direction - Large rooms D_{nT} (dB)	Vertical direction - Small rooms D_{nT} (dB)
50	36.0	38.6	37.7
63	35.8	38.3	37.5
80	35.5	38.1	37.3
100	35.2	37.8	37.0
125	33.4	36.6	35.8
160	38.5	41.6	40.9
200	41.5	44.7	43.9
250	43.6	46.7	46.0
315	46.7	49.8	49.0
400	49.7	52.8	52.1
500	51.7	54.8	54.1
630	53.8	56.8	56.1
800	55.9	58.9	58.2
1000	57.9	60.9	60.2
1250	61.0	63.8	63.1
1600	64.0	66.8	66.0
2000	66.0	68.3	67.4
2500	67.9	69.5	68.4
3150	70.0	71.5	70.4
4000	73.1	74.8	73.7
5000	77.1	77.8	76.4
$D_{nT,w}$ =	54	57	57
C =	-1	-1	-2
C_{tr} =	-6	-6	-7
$C_{(50-3150)}$ =	-1	-1	-2
$C_{tr(50-3150)}$ =	-7	-7	-8
$D_{nT,w} + C$ =	53	56	55
$D_{nT,w} + C_{50}$ =	53	56	55
$D_{nT,w} + C_{I40}$ =	56	59	58
$D_{nT,w} + C_{IndoorA}$ =	57	60	59
$D_{nT,w} + C_{Indoor40}$ =	58	61	61

Figure 3.3.1: Airborne sound insulation for the modern concrete-based building.

3.4 - Modern wood-based building

Figure 3.4.1 presents the airborne sound insulation obtained to the horizontal and vertical direction for the modern wood-based building.



Frequency (Hz)	Horizontal Direction D_{nT} (dB)	Vertical direction - Large rooms D_{nT} (dB)	Vertical direction - Small rooms D_{nT} (dB)
50	17.1	23.6	23.0
63	21.9	34.0	32.2
80	28.3	36.7	35.1
100	27.6	38.8	36.9
125	35.7	43.1	41.7
160	39.1	42.6	41.2
200	42.6	45.5	44.3
250	51.0	48.4	47.0
315	54.6	50.7	49.2
400	54.7	49.9	48.5
500	55.5	51.1	49.6
630	58.1	54.4	52.7
800	59.6	56.4	54.7
1000	59.1	56.2	54.5
1250	60.6	57.7	56.0
1600	61.1	58.3	56.6
2000	59.6	56.8	55.0
2500	58.1	55.2	53.5
3150	60.4	57.7	55.9
4000	62.6	62.1	60.4
5000	63.0	63.6	61.8
$D_{nT,w}$ =	56	55	54
C =	-3	-1	-1
C_{tr} =	-10	-3	-4
$C_{(50-3150)}$ =	-6	-1	-2
$C_{tr(50-3150)}$ =	-17	-9	-9
$D_{nT,w}$ + C =	53	54	53
$D_{nT,w}$ + C_{50} =	50	54	52
$D_{nT,w}$ + C_{I40} =	56	56	54
$D_{nT,w}$ + $C_{IndoorA}$ =	58	56	54
$D_{nT,w}$ + $C_{Indoor40}$ =	59	56	55

Figure 3.4.1: Airborne sound insulation for the modern wood-based building.

3.5 - Building performance and building classes

Table 3.5.1 shows a summary of the obtained airborne sound performance results for the different building configuration under investigation.

Table 3.5.1: Summary of the airborne sound insulation performance in dB for the different building configurations.

	$D_{nT,w} + C$	$D_{nT,w} + C_{50\text{-}3150}$	$D_{nT,w} + C_{I40}$	$D_{nT,w} + C_{IndoorA}$	$D_{nT,w} + C_{Indoor40}$
1930s building					
Horizontal transmission	40	39	41	42	42
Vertical transmission – Large rooms	47	47	49	49	50
Vertical transmission – Small rooms	46	45	48	48	49
1970s building – Concrete based separating wall					
Horizontal transmission	48	48	51	52	53
Vertical transmission – Large rooms	51	50	53	53	54
Vertical transmission – Small rooms	49	49	51	52	53
1970s building – Hollow bricks based separating wall					
Horizontal transmission	40	39	41	41	42
Vertical transmission – Large rooms	50	50	53	53	54
Vertical transmission – Small rooms	48	48	50	51	51
Modern concrete-based building					
Horizontal transmission	53	53	56	57	58
Vertical transmission – Large rooms	56	56	59	60	61
Vertical transmission – Small rooms	55	55	58	59	61
Modern wood-based building					
Horizontal transmission	53	50	56	58	59
Vertical transmission – Large rooms	54	54	56	56	56
Vertical transmission – Small rooms	53	52	54	54	55

Table 3.5.2 shows the building acoustic performance retained to evaluate the performance classes before renovation or upgrade. Since the number of acoustic performance evaluation is limited, the lowest performance is retained for the acoustic performance representative of the building performance (marked in blue in Table 3.5.1). For all building configuration except for the modern wood-based one, the lowest airborne sound insulation performances are related to the horizontal transmission through the separating wall. For the modern wood-based building, the horizontal transmission through the separating wall as well as the vertical transmission between the small rooms are both affecting the lowest airborne sound insulation performance.

Table 3.5.2: Airborne sound insulation performance in dB retained for the classification.

Building type	$D_{nT,w}$ + C	$D_{nT,w}$ + $C_{50\text{-}3150}$	$D_{nT,w}$ + C_{I40}	$D_{nT,w}$ + $C_{IndoorA}$	$D_{nT,w}$ + $C_{Indoor40}$
1930s	40	39	41	42	42
1970s – Concrete based separating wall	48	48	51	52	53
1970s – Hollow bricks based separating wall	40	39	41	41	42
Modern concrete-based	53	53	56	57	58
Modern wood-based	53	50	54	54	55

Table 3.5.3 shows the building acoustic classes performance before renovation or upgrade. Considering $D_{nT,w}$+C as performance index, Qualitel classification shows a 1-class improvement with respect to the ISO/TS 19488 using $D_{nT,w}$+C only.

No difference in classification is found between ISO/TS 19488 (i.e., both $D_{nT,w}$+$C_{50\text{-}3150}$ and $D_{nT,w}$+C) and ISO/TS 19488 using $D_{nT,w}$+$C_{50\text{-}3150}$ only as performance index.

Table 3.5.3: Building class performance before renovation or upgrade.

Building Type	ISO/TS 19488[1]	ISO/TS 19488[2] $D_{nT,w}$ + $C_{50-3150}$ only	ISO/TS 19488[3] $D_{nT,w}$ + C_{I40}	ISO/TS 19488[3] $D_{nT,w}$ + $C_{IndoorA}$	ISO/TS 19488[3] $D_{nT,w}$ + $C_{Indoor40}$	ISO/TS 19488[4] $D_{nT,w}$ + C only	Qualitel[5] $D_{nT,w}$ + C
1930s	F	F	F	F	E	F	E
1970s – Concrete based separating wall	D	D	D	C	C	D	C
1970s – Hollow bricks based separating wall	F	F	F	F	F	F	E
Modern concrete-based	C	C	C	B	C	C	B
Modern wood-based	C	C	B	B	B	C	B

[1] See Table 6.2.1 in Annex A.
[2] See Table 6.2.2 in Annex A.
[3] ISO/TS 19488 does not provide a classification based on this index, thus the classification proposed here is based on the same values that for $D_{nT,w}$+$C_{50-3150}$ given in Table 6.2.3 in Annex A.
[4] See Table 6.2.3 in Annex A.
[5] See Table 6.2.4 in Annex A.

Table 3.5.4 summarizes the loudness evaluation for the different building configurations and different transmission cases investigated, and the different noise source spectra considered.

Table 3.5.4: Summary of the loudness evaluation in sone for the different building configurations before renovation or upgrade.

Input noise source	Pink noise	Indoor Noise NSir1 or NSir2avg	Indoor Noise NSir1 or NSir2avg + 10 dB	Indoor Noise NSir2max
1930s building				
Horizontal transmission	8.2601	3.1491	7.0395	5.8257
Vertical transmission – Large rooms	4.4861	1.3375	3.6466	3.0456
Vertical transmission – Small rooms	5.0731	1.6083	4.1783	3.4934
1970s building – Concrete based separating wall				
Horizontal transmission	3.5567	0.9350	2.7595	2.3418
Vertical transmission – Large rooms	3.1577	0.8166	2.5389	2.0972
Vertical transmission – Small rooms	3.6441	1.0245	2.9742	2.4659
1970s building – Hollow bricks based separating wall				
Horizontal transmission	7.9320	3.1054	6.9218	5.7294
Vertical transmission – Large rooms	3.3124	0.8844	2.6849	2.2089
Vertical transmission – Small rooms	3.9690	1.1731	3.2792	2.7085
Modern concrete-based building				
Horizontal transmission	2.2735	0.4585	1.6501	1.4081
Vertical transmission – Large rooms	1.7040	0.2728	1.1975	1.0017
Vertical transmission – Small rooms	1.8517	0.3110	1.3129	1.0964
Modern wood-based building				
Horizontal transmission	2.9231	0.4427	1.9308	1.5448
Vertical transmission – Large rooms	2.6496	0.5716	2.1031	1.6254
Vertical transmission – Small rooms	3.0760	0.7413	2.4773	1.9396

3.6 - Building classes to reach after renovation or upgrade

Table 3.6.1 shows the building acoustic classes performance that are desired to reach after renovation or upgrade solutions are applied to the building.

The effect of the renovation or update solution will then be investigated on the other indexes considered in this work.

Table 3.6.1: Building class performance to be reached after renovation or upgrade.

Building Type	ISO/TS 19488[1]
1930s	D $D_{nT,w}+C \geq 48$ dB
1970s – Concrete based separating wall	B $D_{nT,w}+C_{50\text{-}3150} \geq 54$ dB
1970s – Hollow bricks based separating wall	D $D_{nT,w}+C \geq 48$ dB
Modern concrete-based	A $D_{nT,w}+C_{50\text{-}3150} \geq 58$ dB
Modern wood-based	A $D_{nT,w}+C_{50\text{-}3150} \geq 58$ dB

[1] See Table 6.2.1 in Annex A

4 - TASK 2 – AIRBORNE SOUND INSULATION FOR BUILDINGS AFTER MODIFICATIONS

The results of the acoustic performance evaluation are presented in this section for the different building types after renovation or upgrade is undertaken with respect to their acoustic situation.

The building modification solutions are defined such that the evaluated acoustic performance reaches an improvement of 2 classes regarding air-borne sound insulation based on ISO/TS 19488. The necessary solution is described for each building type considered in this investigation.

Since the number of acoustic performance evaluation is limited, the lowest performance is retained for the acoustic performance representative of the building performance.

The loudness evaluation before or after renovation or upgrade is based on input noise source spectra given in Annex A.

In the following, the mention “independent frame” for linings correspond to a lining mounted on a metallic studs/rails system without any direct connection to the supporting wall.

The linings, suspended ceilings, floating floor systems are not continuous between the different rooms, i.e., wall/floor treatments used to improve the building acoustic performance are applied in each room separately.

A meeting with Eurima on March 24th 2025 allowed a first discussion on the obtained results. Consequently, the acoustic performance of the step-by-step building modification has been added in Annex B for the different building types considered in this work.

4.1 - Building from the 1930s

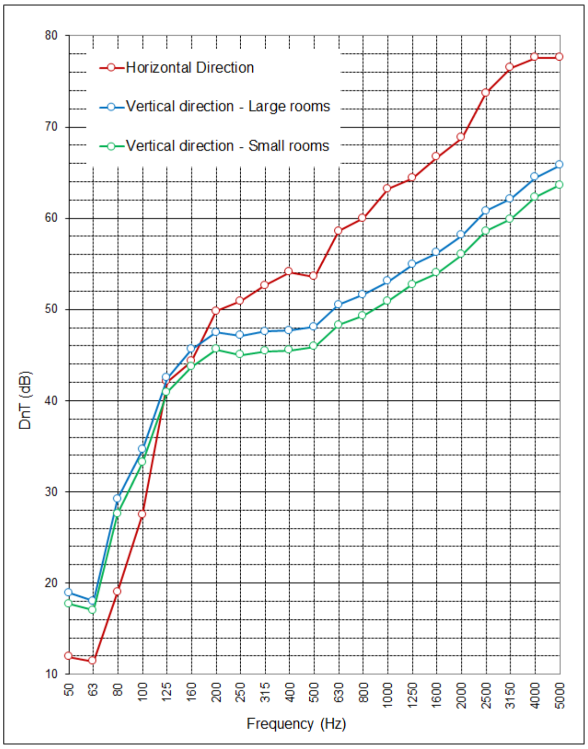
Based on ISO/TS 19488, the building original configuration reaches a performance class F (the lowest) and the applied renovation should be determined to reach a class D corresponding to $D_{nT,w}+C \geq 48$ dB.

The proposed basic renovation solution is based on the following elements:

- Façade: lining composed of mineral wool 100 mm with a single layer of 12.5 mm thick plaster boards on independent frame ($\Delta(R_w+C)_{heavy} = 14$ dB);
- Suspended ceiling: 100 mm cavity filled with 80 mm of mineral wool with a single layer of 12.5 mm thick plaster boards ($\Delta(R_w+C)_{heavy} = 15$ dB);
- Separating wall: lining composed of 45 mm of mineral wool with a single layer of 12.5 mm thick plaster boards on independent frame ($\Delta(R_w+C)_{heavy} = 13$ dB).

Figure 4.1.1 presents the airborne sound insulation obtained to the horizontal and vertical direction for the 1930s building after renovation. In this case the renovation concerns the implementation of lining on both sides of the separating wall, lining on façade and suspended ceiling.

Table 4.1.1 summarizes the acoustic performance before and after renovation for the different transmission cases investigated.



	Horizontal Direction	Vertical direction - Large rooms	Vertical direction - Small rooms
Frequency (Hz)	D_{nT} (dB)	D_{nT} (dB)	D_{nT} (dB)
50	11.9	18.9	17.7
63	11.4	18.0	17.0
80	19.0	29.2	27.6
100	27.5	34.6	33.2
125	42.1	42.5	40.9
160	44.3	45.6	43.7
200	49.8	47.5	45.6
250	50.9	47.1	45.0
315	52.6	47.6	45.4
400	54.1	47.7	45.5
500	53.6	48.1	45.9
630	58.6	50.5	48.3
800	60.0	51.6	49.3
1000	63.2	53.1	50.9
1250	64.4	54.9	52.7
1600	66.7	56.2	54.0
2000	68.8	58.1	56.0
2500	73.7	60.8	58.6
3150	76.5	62.1	59.9
4000	77.6	64.5	62.3
5000	77.6	65.8	63.6

$D_{nT,w}$ =	59	54	51
C =	-4	-1	0
C_{tr} =	-12	-5	-3
$C_{(50-3150)}$ =	-14	-5	-3
$C_{tr(50-3150)}$ =	-27	-15	-14
$D_{nT,w}$ + C =	55	53	51
$D_{nT,w}$ + C_{50} =	45	49	48
$D_{nT,w}$ + C_{I40} =	53	54	52
$D_{nT,w}$ + $C_{IndoorA}$ =	57	54	52
$D_{nT,w}$ + $C_{Indoor40}$ =	61	55	53

Figure 4.1.1: Airborne sound insulation for the 1930s building after renovation.

Table 4.1.1: Summary of the airborne sound insulation performance in dB for the 1930s building, before and after renovation.

	$D_{nT,w} + C$	$D_{nT,w} + C_{50\text{-}3150}$	$D_{nT,w} + C_{I40}$	$D_{nT,w} + C_{IndoorA}$	$D_{nT,w} + C_{Indoor40}$
Before renovation					
Horizontal transmission	40	39	41	42	42
Vertical transmission – Large rooms	47	47	49	49	50
Vertical transmission – Small rooms	46	45	48	48	49
After renovation					
Horizontal transmission	55	45	53	57	61
Vertical transmission – Large rooms	53	49	54	54	55
Vertical transmission – Small rooms	51	48	52	52	53

Table 4.1.2 shows the building acoustic performance retained to evaluate the performance classes (based as previously mentioned on the lowest airborne sound insulation performance).

Table 4.1.2: 1930s building – Airborne sound insulation performance in dB before and after renovation.

1930s building	$D_{nT,w} + C$	$D_{nT,w} + C_{50\text{-}3150}$	$D_{nT,w} + C_{I40}$	$D_{nT,w} + C_{IndoorA}$	$D_{nT,w} + C_{Indoor40}$
Before renovation	40	39	41	42	42
After renovation	51	45	52	52	53

Table 4.1.3 shows the building acoustic classes performance after renovation.

Table 4.1.3: 1930s building – Building class performance before and after renovation.

1930s building	ISO/TS 19488[1]	ISO/TS 19488[2] $D_{nT,w}$ + $C_{50-3150}$ only	ISO/TS 19488[3] $D_{nT,w}$ + C_{I40}	ISO/TS 19488[3] $D_{nT,w}$ + $C_{IndoorA}$	ISO/TS 19488[3] $D_{nT,w}$ + $C_{Indoor40}$	ISO/TS 19488[4] $D_{nT,w}$ + C only	Qualitel[5] $D_{nT,w}$ + C
Before renovation	F	F	F	F	E	F	E
After renovation	D	E	C	C	C	D	C

[1] See Table 6.2.1 in Annex A.
[2] See Table 6.2.2 in Annex A.
[3] ISO/TS 19488 does not provide a classification based on this index, thus the classification proposed here is based on the same values that for $D_{nT,w}$+$C_{50-3150}$ given in Table 6.2.3 in Annex A.
[4] See Table 6.2.3 in Annex A.
[5] See Table 6.2.4 in Annex A.

Table 4.1.4 summarizes the loudness evaluation before and after renovation for the different transmission cases investigated and the different noise source spectra considered.

Table 4.1.4: Summary of the loudness evaluation in sone for the 1930s building, before and after renovation.

Input noise source	Pink noise	Indoor Noise NSir1 or NSir2avg	Indoor Noise NSir1 or NSir2avg + 10 dB	Indoor Noise NSir2max
Before renovation				
Horizontal transmission	8.2601	3.1491	7.0395	5.8257
Vertical transmission – Large rooms	4.4861	1.3375	3.6466	3.0456
Vertical transmission – Small rooms	5.0731	1.6083	4.1783	3.4934
After renovation				
Horizontal transmission	3.5092	0.3769	1.5473	1.4861
Vertical transmission – Large rooms	3.4245	0.7018	2.4159	2.027
Vertical transmission – Small rooms	4.0456	0.9537	2.9454	2.5058

4.2 - Building from the 1970s

4.2.1 - Concrete based separating wall

Based on ISO/TS 19488, the building original configuration reaches a performance class D and the applied renovation should be determined to reach a class B corresponding to $D_{nT,w}+C_{50\text{-}3150} \geq 54$ dB.

The proposed basic renovation solution is based on the following elements:

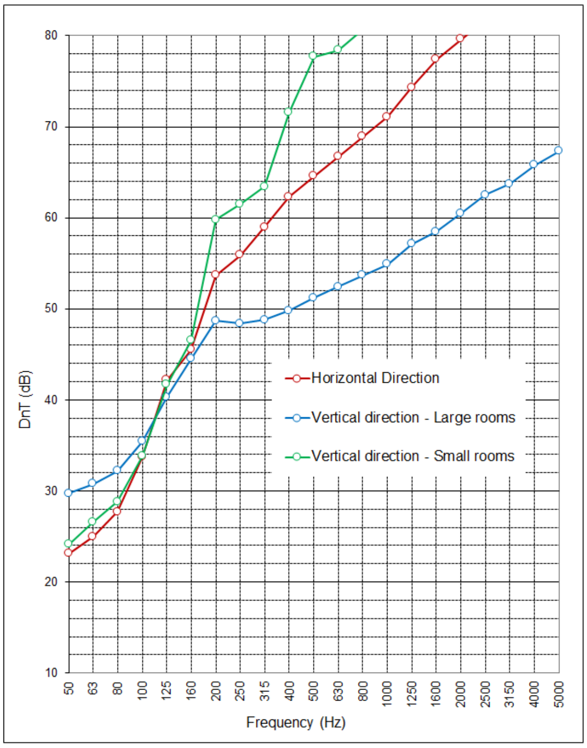
- Façade: lining composed of mineral wool 100 mm with a single layer of 12.5 mm thick plaster boards on independent frame ($\Delta(R_w+C)_{heavy}$ = 14 dB);
- Plastic floor covering $\Delta L_w \geq 19$ dB;
- Suspended ceiling : 50 mm cavity filled with 45 mm of mineral wool with a single layer of 12.5 mm thick plaster boards ($\Delta(R_w+C)_{heavy}$ = 13 dB);
- Separating wall: lining composed of 45 mm of mineral wool with a single layer of 12.5 mm thick plaster boards on independent frame ($\Delta(R_w+C)_{heavy}$ = 13 dB).

In order to reach desired acoustic performance, the solution has been adapted to include:

- Small rooms partition walls: lining composed of 45 mm of mineral wool with a single layer of 12.5 mm thick plaster boards on independent frame ($\Delta(R_w+C)_{heavy}$ = 13 dB)
- Separating wall on small rooms side: lining composed of 45 mm of mineral wool with a single layer of 12.5 mm thick plaster boards on independent frame ($\Delta(R_w+C)_{heavy}$ = 13 dB)
- Separating wall on large rooms side: lining composed of 100 mm of mineral wool with a single layer of 12.5 mm thick plaster boards on independent frame ($\Delta(R_w+C)_{heavy}$ = 14 dB).

Figure 4.2.1 present the airborne sound insulation obtained to the horizontal and vertical direction for the 1970s building after renovation in the case of a concrete based separating wall.

Table 4.2.1 summarizes the acoustic performance before and after renovation for the different transmission cases investigated.



Frequency (Hz)	Horizontal Direction D_{nT} (dB)	Vertical direction - Large rooms D_{nT} (dB)	Vertical direction - Small rooms D_{nT} (dB)
50	23.1	29.7	24.1
63	25.0	30.8	26.6
80	27.7	32.2	28.8
100	33.7	35.4	33.8
125	42.2	40.3	41.7
160	45.5	44.5	46.5
200	53.7	48.7	59.8
250	55.9	48.4	61.5
315	59.0	48.8	63.4
400	62.3	49.8	71.6
500	64.6	51.2	77.7
630	66.7	52.4	78.4
800	68.9	53.7	80.7
1000	71.1	54.9	86.0
1250	74.3	57.1	89.8
1600	77.4	58.5	92.9
2000	79.6	60.5	96.6
2500	81.7	62.5	96.5
3150	83.9	63.7	94.4
4000	87.0	65.8	93.9
5000	92.2	67.3	95.4
$D_{nT,w}$ =	64	55	67
C =	-4	-1	-6
C_{tr} =	-12	-4	-14
$C_{(50-3150)}$ =	-9	-1	-11
$C_{tr(50-3150)}$ =	-21	-8	-23
$D_{nT,w}$ + C =	60	54	61
$D_{nT,w}$ + C_{50} =	55	54	56
$D_{nT,w}$ + C_{I40} =	62	56	64
$D_{nT,w}$ + $C_{IndoorA}$ =	66	56	68
$D_{nT,w}$ + $C_{Indoor40}$ =	70	57	74

Figure 4.2.1: Airborne sound insulation for the 1970s building with concrete based separating wall, after renovation.

Table 4.2.1: Summary of the airborne sound insulation performance in dB for the 1970s building with concrete based separating wall, before and after renovation.

	$D_{nT,w}$ + C	$D_{nT,w}$ + $C_{50-3150}$	$D_{nT,w}$ + C_{I40}	$D_{nT,w}$ + $C_{IndoorA}$	$D_{nT,w}$ + $C_{Indoor40}$
Before renovation					
Horizontal transmission	48	48	51	52	53
Vertical transmission – Large rooms	51	50	53	53	54
Vertical transmission – Small rooms	49	49	51	52	53
After renovation					
Horizontal transmission	60	55	62	66	70
Vertical transmission – Large rooms	54	54	56	56	57
Vertical transmission – Small rooms	61	56	64	68	74

Table 4.2.2 shows the building acoustic performance retained to evaluate the performance classes.

Table 4.2.2: 1970s building with concrete based separating wall – Airborne sound insulation performance in dB before and after renovation.

1970s building	$D_{nT,w}$ + C	$D_{nT,w}$ + $C_{50\text{-}3150}$	$D_{nT,w}$ + C_{I40}	$D_{nT,w}$ + $C_{IndoorA}$	$D_{nT,w}$ + $C_{Indoor40}$
Before renovation	48	48	51	52	53
After renovation	54	54	56	56	57

Table 4.2.3 shows the building acoustic classes performance after renovation.

Table 4.2.3: 1970s building with concrete based separating wall – Building class performance before and after renovation.

1970s building	ISO/TS 19488[1]	ISO/TS 19488[2] $D_{nT,w}$ + $C_{50\text{-}3150}$ only	ISO/TS 19488[3] $D_{nT,w}$ + C_{I40}	ISO/TS 19488[3] $D_{nT,w}$ + $C_{IndoorA}$	ISO/TS 19488[3] $D_{nT,w}$ + $C_{Indoor40}$	ISO/TS 19488[4] $D_{nT,w}$ + C only	Qualitel[5] $D_{nT,w}$ + C
Before renovation	D	D	D	C	C	D	C
After renovation	B	B	B	B	B	C	B

[1] See Table 6.2.1 in Annex A.
[2] See Table 6.2.2 in Annex A.
[3] ISO/TS 19488 does not provide a classification based on this index, thus the classification proposed here is based on the same values that for $D_{nT,w}$+$C_{50\text{-}3150}$ given in Table 6.2.3 in Annex A.
[4] See Table 6.2.3 in Annex A.
[5] See Table 6.2.4 in Annex A.

Table 4.2.4 summarizes the loudness evaluation before and after renovation for the different transmission cases investigated and the different noise source spectra considered.

Table 4.2.4: Summary of the loudness evaluation in sone for the 1970s building with concrete based separating wall, before and after renovation.

Input noise source	Pink noise	Indoor Noise NSir1 or NSir2avg	Indoor Noise NSir1 or NSir2avg + 10 dB	Indoor Noise NSir2max
Before renovation				
Horizontal transmission	3.5567	0.9350	2.7595	2.3418
Vertical transmission – Large rooms	3.1577	0.8166	2.5389	2.0972
Vertical transmission – Small rooms	3.6441	1.0245	2.9742	2.4659
After renovation				
Horizontal transmission	1.2947	0.0351	0.4947	0.4637
Vertical transmission – Large rooms	2.5016	0.504	1.9208	1.5532
Vertical transmission – Small rooms	1.1084	0.0227	0.2968	0.3137

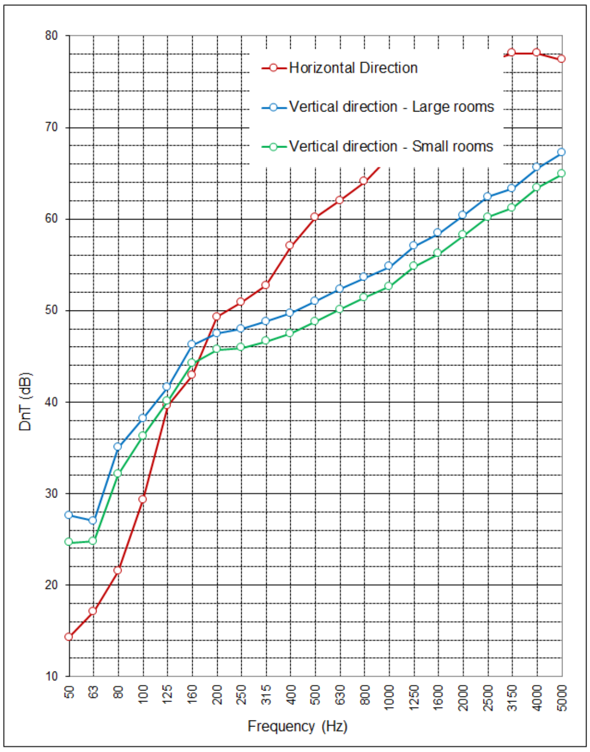
4.2.2 - Brick based separating wall

Based on ISO/TS 19488, the building original configuration reaches a performance class F and the applied renovation should be determined to reach a class D corresponding to $D_{nT,w}+C \geq 48$ dB.

The proposed basic renovation solution is based on the following elements:

- Façade: lining composed of mineral wool 100 mm with a single layer of 12.5 mm thick plaster boards on independent frame ($\Delta(R_w+C)_{heavy}$ = 14 dB);
- Plastic floor covering $\Delta L_w \geq 19$ dB;
- Suspended ceiling: 50 mm cavity filled with 45 mm of mineral wool with a single layer of 12.5 mm thick plaster boards ($\Delta(R_w+C)_{heavy}$ = 13 dB);
- Separating wall: lining composed of 45 mm of mineral wool with a single layer of 12.5 mm thick plaster boards on independent frame ($\Delta(R_w+C)_{heavy}$ = 13 dB).

Figure 4.2.2 present the airborne sound insulation obtained to the horizontal and vertical direction for the 1970s building after renovation in the case of a brick based separating wall.



Frequency (Hz)	Horizontal Direction D_{nT} (dB)	Vertical direction - Large rooms D_{nT} (dB)	Vertical direction - Small rooms D_{nT} (dB)
50	14.3	27.6	24.6
63	17.1	27.0	24.8
80	21.5	35.0	32.1
100	29.3	38.2	36.3
125	39.6	41.6	40.1
160	42.9	46.2	44.2
200	49.3	47.5	45.7
250	50.9	48.0	45.9
315	52.7	48.8	46.6
400	57.0	49.7	47.5
500	60.2	51.0	48.8
630	62.0	52.3	50.1
800	64.1	53.6	51.4
1000	66.9	54.8	52.6
1250	70.0	57.0	54.8
1600	73.2	58.4	56.2
2000	75.4	60.4	58.2
2500	77.3	62.4	60.2
3150	78.1	63.3	61.2
4000	78.1	65.6	63.4
5000	77.4	67.2	64.9
$D_{nT,w}$ =	60	55	53
C =	-4	-1	-1
C_{tr} =	-12	-4	-4
$C_{(50-3150)}$ =	-12	-1	-2
$C_{tr(50-3150)}$ =	-25	-9	-9
$D_{nT,w}$ + C =	56	54	52
$D_{nT,w}$ + C_{50} =	48	54	51
$D_{nT,w}$ + C_{I40} =	56	56	54
$D_{nT,w}$ + $C_{IndoorA}$ =	60	56	54
$D_{nT,w}$ + $C_{Indoor40}$ =	64	57	55

Figure 4.2.2: Airborne sound insulation for the 1970s building with brick-based separating wall, after renovation.

Table 4.2.5 summarizes the acoustic performance before and after renovation for the different transmission cases investigated.

Table 4.2.5: Summary of the airborne sound insulation performance in dB for the 1970s building with brick-based separating wall before and after renovation.

	$D_{nT,w}$ + C	$D_{nT,w}$ + $C_{50\text{-}3150}$	$D_{nT,w}$ + C_{I40}	$D_{nT,w}$ + $C_{IndoorA}$	$D_{nT,w}$ + $C_{Indoor40}$
Before renovation					
Horizontal transmission	40	39	41	41	42
Vertical transmission – Large rooms	50	50	53	53	54
Vertical transmission – Small rooms	48	48	50	51	51
After renovation					
Horizontal transmission	56	48	56	60	64
Vertical transmission – Large rooms	54	54	56	56	57
Vertical transmission – Small rooms	52	51	54	54	55

Table 4.2.6 shows the building acoustic performance retained to evaluate the performance classes.

Table 4.2.6: 1970s building with brick based separating wall – Airborne sound insulation performance in dB before and after renovation.

1970s building	$D_{nT,w}$ + C	$D_{nT,w}$ + $C_{50\text{-}3150}$	$D_{nT,w}$ + C_{I40}	$D_{nT,w}$ + $C_{IndoorA}$	$D_{nT,w}$ + $C_{Indoor40}$
Before renovation	40	39	41	41	42
After renovation	52	48	54	54	55

Table 4.2.7 shows the building acoustic classes performance after renovation.

Table 4.2.7: 1970s building with brick based separating wall – Building class performance before and after renovation.

1730s building	ISO/TS 19488[1]	ISO/TS 19488[2] $D_{nT,w} + C_{50\text{-}3150}$ only	ISO/TS 19488[3] $D_{nT,w} + C_{I40}$	ISO/TS 19488[3] $D_{nT,w} + C_{IndoorA}$	ISO/TS 19488[3] $D_{nT,w} + C_{Indoor40}$	ISO/TS 19488[4] $D_{nT,w}$ + C only	Qualitel[5] $D_{nT,w}$ + C
Before renovation	F	F	F	F	F	F	E
After renovation	C	D	B	B	B	C	C

[1] See Table 6.2.1 in Annex A.
[2] See Table 6.2.2 in Annex A.
[3] ISO/TS 19488 does not provide a classification based on this index, thus the classification proposed here is based on the same values that for $D_{nT,w}+C_{50\text{-}3150}$ given in Table 6.2.3 in Annex A.
[4] See Table 6.2.3 in Annex A.
[5] See Table 6.2.4 in Annex A.

Table 4.2.8 summarizes the loudness evaluation before and after renovation for the different transmission cases investigated and the different noise source spectra considered.

Table 4.2.8: Summary of the loudness evaluation in sone for the 1970s building with brick based separating wall, before and after renovation.

Input noise source	Pink noise	Indoor Noise NSir1 or NSir2avg	Indoor Noise NSir1 or NSir2avg + 10 dB	Indoor Noise NSir2max
Before renovation				
Horizontal transmission	7.9320	3.1054	6.9218	5.7294
Vertical transmission – Large rooms	3.3124	0.8844	2.6849	2.2089
Vertical transmission – Small rooms	3.9690	1.1731	3.2792	2.7085
After renovation				
Horizontal transmission	2.3336	0.1939	1.0185	0.9933
Vertical transmission – Large rooms	2.5126	0.5089	1.9271	1.5547
Vertical transmission – Small rooms	3.0979	0.7161	2.4058	1.9657

4.3 - Modern concrete-based building

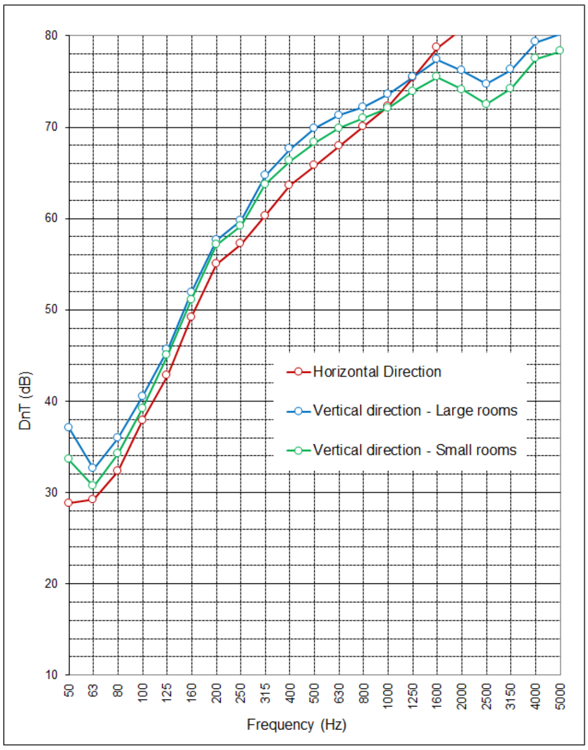
Based on ISO/TS 19488, the building original configuration reaches a performance class C and the applied renovation should be determined to reach a class A corresponding to $D_{nT,w}+C_{50\text{-}3150}$ ≥ 58 dB.

The proposed upgrading solution is based on the following elements:

- Façade: lining composed of mineral wool 100 mm with a single layer of 12.5 mm thick plaster boards on independent frame ($\Delta(R_w+C)_{heavy}$ = 14 dB);
- Floating screed 40 mm on mineral 20 mm wool with ΔL_w ≥ 27 dB and $\Delta(R_w+C)_{heavy\ floorl}$ ≥ 10 dB;
- Separating wall: lining composed of mineral wool 45 mm with a single layer of 12.5 mm thick plaster boards on independent frame ($\Delta(R_w+C)_{heavy}$ = 13 dB) on small room size and lining composed of mineral wool 100 mm with a single layer of 12.5 mm thick plaster boards on independent frame ($\Delta(R_w+C)_{heavy}$ = 14 dB) on large room size;

Figure 4.3.1 presents the airborne sound insulation obtained to the horizontal and vertical direction for the modern concrete-based building.

Table 4.3.1 summarizes the acoustic performance before and after renovation for the different transmission cases investigated.



Frequency (Hz)	Horizontal Direction D_{nT} (dB)	Vertical direction - Large rooms D_{nT} (dB)	Vertical direction - Small rooms D_{nT} (dB)
50	28.8	37.1	33.6
63	29.2	32.6	30.7
80	32.3	35.9	34.2
100	37.9	40.5	39.2
125	42.8	45.6	45.0
160	49.2	51.9	51.1
200	55.0	57.6	57.1
250	57.2	59.8	59.2
315	60.3	64.7	63.7
400	63.6	67.6	66.3
500	65.8	69.9	68.3
630	67.9	71.3	69.9
800	70.1	72.2	71.0
1000	72.3	73.6	72.1
1250	75.4	75.5	73.9
1600	78.7	77.4	75.5
2000	80.8	76.2	74.1
2500	82.9	74.7	72.5
3150	85.1	76.3	74.2
4000	88.3	79.3	77.5
5000	92.2	80.2	78.3

$D_{nT,w}$ =	66	69	68
C =	-3	-4	-4
C_{tr} =	-10	-10	-11
$C_{(50-3150)}$ =	-7	-7	-7
$C_{tr(50-3150)}$ =	-18	-17	-18

$D_{nT,w}$ + C =	63	65	64
$D_{nT,w}$ + C_{50} =	59	62	61

$D_{nT,w}$ + C_{I40} =	66	68	67
$D_{nT,w}$ + $C_{IndoorA}$ =	69	71	70
$D_{nT,w}$ + $C_{Indoor40}$ =	72	73	72

Figure 4.3.1: Airborne sound insulation for the modern concrete-based building after upgrade.

Table 4.3.1: Summary of the airborne sound insulation performance in dB for the modern concrete-based building before and after upgrade.

	$D_{nT,w}$ + C	$D_{nT,w}$ + $C_{50-3150}$	$D_{nT,w}$ + C_{I40}	$D_{nT,w}$ + $C_{IndoorA}$	$D_{nT,w}$ + $C_{Indoor40}$
Before upgrade					
Horizontal transmission	53	53	56	57	58
Vertical transmission – Large rooms	56	56	59	60	61
Vertical transmission – Small rooms	55	55	58	59	61
After upgrade					
Horizontal transmission	63	59	66	69	72
Vertical transmission – Large rooms	65	62	68	71	73
Vertical transmission – Small rooms	64	61	67	70	72

Table 4.3.2 shows the building acoustic performance retained to evaluate the performance classes.

Table 4.3.2: Modern concrete-based building – Airborne sound insulation performance in dB before and after upgrade.

Modern concrete building	$D_{nT,w} + C$	$D_{nT,w} + C_{50\text{-}3150}$	$D_{nT,w} + C_{I40}$	$D_{nT,w} + C_{IndoorA}$	$D_{nT,w} + C_{Indoor40}$
Before upgrade	53	53	56	57	58
After upgrade	63	59	66	69	72

Table 4.3.3 shows the building acoustic classes performance after renovation.

Table 4.3.3: Modern concrete-based building – Building class performance before and after upgrade.

Modern concrete building	ISO/TS 19488[1]	ISO/TS 19488[2] $D_{nT,w} + C_{50\text{-}3150}$ only	ISO/TS 19488[3] $D_{nT,w} + C_{I40}$	ISO/TS 19488[3] $D_{nT,w} + C_{IndoorA}$	ISO/TS 19488[3] $D_{nT,w} + C_{Indoor40}$	ISO/TS 19488[4] $D_{nT,w} + C$ only	Qualitel[5] $D_{nT,w} + C$
Before upgrade	C	C	C	B	C	C	B
After upgrade	A	A	A	A	A	A	A+

[1] See Table 6.2.1 in Annex A.
[2] See Table 6.2.2 in Annex A.
[3] ISO/TS 19488 does not provide a classification based on this index, thus the classification proposed here is based on the same values that for $D_{nT,w}+C_{50\text{-}3150}$ given in Table 6.2.3 in Annex A.
[4] See Table 6.2.3 in Annex A.
[5] See Table 6.2.4 in Annex A.

Table 4.3.4 summarizes the loudness evaluation before and after upgrade for the different transmission cases investigated and the different noise source spectra considered.

Table 4.3.4: Summary of the loudness evaluation in sone for the modern concrete-based building, before and after upgrade.

Input noise source	Pink noise	Indoor Noise NSir1 or NSir2avg	Indoor Noise NSir1 or NSir2avg + 10 dB	Indoor Noise NSir2max
Before upgrade				
Horizontal transmission	2.2735	0.4585	1.6501	1.4081
Vertical transmission – Large rooms	1.7040	0.2728	1.1975	1.0017
Vertical transmission – Small rooms	1.8517	0.3110	1.3129	1.0964
After upgrade				
Horizontal transmission	0.9083	0.0053	0.3298	0.2926
Vertical transmission – Large rooms	0.6101	0.0000	0.1830	0.1483
Vertical transmission – Small rooms	0.7546	0.0000	0.2635	0.2040

4.4 - Modern wood-based building

Based on ISO/TS 19488, the building original configuration reaches a performance class C and the applied renovation should be determined to reach a class A corresponding to $D_{nT,w}+C_{50\text{-}3150} \geq 58$ dB.

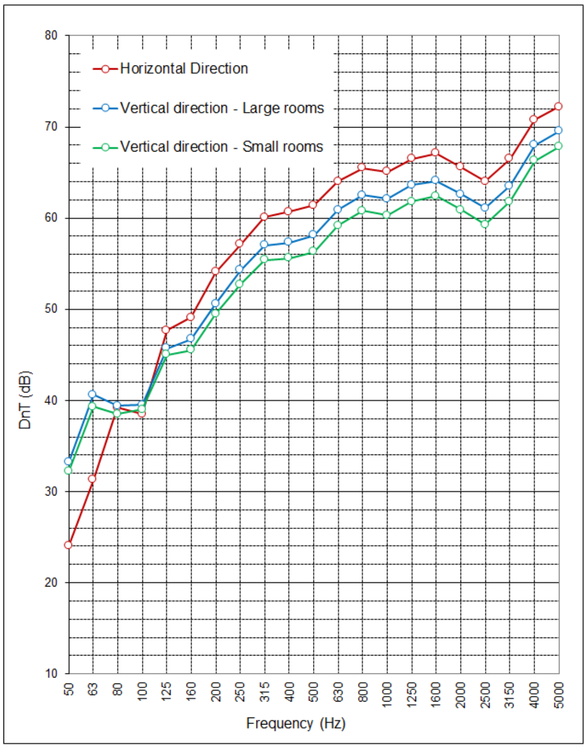
The proposed upgrading solution is based on the following elements:

- Separating wall: lining with 100 mm of mineral wool and a double layer of 12.5 mm thick plaster boards on independent frame, on the small room sides;
- Separating wall: lining with 100 mm of mineral wool and a single layer of 12.5 mm thick plaster boards on independent frame, on the large room sides;
- Floating screed 60 mm in thickness on 15 mm of mineral wool $\Delta(R_w+C) \geq 17$ dB;
- Suspended ceiling: 150 mm cavity filled with 130 mm of mineral wool and a double layer of 12.5 mm thick plaster boards.

Changing the façade lining has no effect on the result since the transmission path associated to the façade is not contributing much to the global performance (façade transmission path : $D_{nT,w}+C$ and $D_{nT,w}+C_{50\text{-}3150} \geq 70$ dB).

Figure 4.4.1 presents the airborne sound insulation obtained to the horizontal and vertical direction for the modern concrete-based building.

Table 4.4.1 summarizes the acoustic performance before and after renovation for the different transmission cases investigated.



	Horizontal Direction	Vertical direction - Large rooms	Vertical direction - Small rooms
Frequency (Hz)	D_{nT} (dB)	D_{nT} (dB)	D_{nT} (dB)
50	24.0	33.2	32.2
63	31.3	40.6	39.3
80	39.2	39.4	38.5
100	38.5	39.5	39.0
125	47.7	45.7	45.0
160	49.1	46.7	45.5
200	54.1	50.6	49.5
250	57.1	54.3	52.7
315	60.1	57.0	55.4
400	60.7	57.3	55.6
500	61.4	58.1	56.3
630	64.0	60.9	59.2
800	65.5	62.5	60.8
1000	65.1	62.1	60.3
1250	66.5	63.6	61.8
1600	67.1	64.1	62.4
2000	65.6	62.6	60.9
2500	64.0	61.1	59.3
3150	66.5	63.5	61.8
4000	70.8	68.0	66.3
5000	72.2	69.5	67.8
$D_{nT,w}$ =	64	61	60
C =	-2	-1	-2
C_{tr} =	-8	-5	-5
$C_{(50-3150)}$ =	-5	-2	-2
$C_{tr(50-3150)}$ =	-17	-8	-9
$D_{nT,w}$ + C =	62	60	58
$D_{nT,w}$ + C_{50} =	59	59	58
$D_{nT,w}$ + C_{I40} =	63	62	60
$D_{nT,w}$ + $C_{IndoorA}$ =	65	62	60
$D_{nT,w}$ + $C_{Indoor40}$ =	65	62	61

Figure 4.4.1: Airborne sound insulation for the modern wood-based building after upgrade.

Table 4.4.1: Summary of the airborne sound insulation performance in dB for the modern wood-based building before and after upgrade.

	$D_{nT,w}$ + C	$D_{nT,w}$ + $C_{50\text{-}3150}$	$D_{nT,w}$ + C_{I40}	$D_{nT,w}$ + $C_{IndoorA}$	$D_{nT,w}$ + $C_{Indoor40}$
Before upgrade					
Horizontal transmission	53	50	56	58	59
Vertical transmission – Large rooms	54	54	56	56	56
Vertical transmission – Small rooms	53	52	54	54	55
After upgrade					
Horizontal transmission	62	59	63	65	65
Vertical transmission – Large rooms	60	59	62	62	62
Vertical transmission – Small rooms	58	58	60	60	61

Table 4.4.2 shows the building acoustic performance retained to evaluate the performance classes.

Table 4.4.2: Modern wood-based building – Airborne sound insulation performance in dB before and after upgrade.

Modern wood-based building	$D_{nT,w}$ + C	$D_{nT,w}$ + $C_{50\text{-}3150}$	$D_{nT,w}$ + C_{I40}	$D_{nT,w}$ + $C_{IndoorA}$	$D_{nT,w}$ + $C_{Indoor40}$
Before upgrade	53	50	54	54	55
After upgrade	58	58	60	60	61

Table 4.4.3 shows the building acoustic classes performance after renovation.

Table 4.4.3: Modern wood-based building – Building class performance before and after upgrade.

Modern wood-based building	ISO/TS 19488[1]	ISO/TS 19488[2] $D_{nT,w} + C_{50\text{-}3150}$ only	ISO/TS 19488[3] $D_{nT,w} + C_{I40}$	ISO/TS 19488[3] $D_{nT,w} + C_{IndoorA}$	ISO/TS 19488[3] $D_{nT,w} + C_{Indoor40}$	ISO/TS 19488[4] $D_{nT,w}$ + C only	Qualitel[5] $D_{nT,w}$ + C
Before upgrade	C	C	B	B	B	C	B
After upgrade	A	A	A	A	A	B	A

[1] See Table 6.2.1 in Annex A.
[2] See Table 6.2.2 in Annex A.
[3] ISO/TS 19488 does not provide a classification based on this index, thus the classification proposed here is based on the same values that for $D_{nT,w}+C_{50\text{-}3150}$ given in Table 6.2.3 in Annex A.
[4] See Table 6.2.3 in Annex A.
[5] See Table 6.2.4 in Annex A.

Table 4.4.4 summarizes the loudness evaluation before and after upgrade for the different transmission cases investigated and the different noise source spectra considered.

Table 4.4.4: Summary of the loudness evaluation in sone for the modern wood-based building, before and after upgrade.

Input noise source	Pink noise	Indoor Noise NSir1 or NSir2avg	Indoor Noise NSir1 or NSir2avg + 10 dB	Indoor Noise NSir2max
Before upgrade				
Horizontal transmission	2.9231	0.4427	1.9308	1.5448
Vertical transmission – Large rooms	2.6496	0.5716	2.1031	1.6254
Vertical transmission – Small rooms	3.0760	0.7413	2.4773	1.9396
After upgrade				
Horizontal transmission	1.2099	0.0399	0.7153	0.5165
Vertical transmission – Large rooms	1.4360	0.1475	1.0518	0.7634
Vertical transmission – Small rooms	1.7135	0.2363	1.3023	0.9626

5 - RESULTS ANALYSIS

In this section, the results in terms of SNQ values are analyzed for each considered configuration.

Note that for simplicity the following terms are used in Figure 5.1.1, Figure 5.2.1, Figure 5.2.2, Figure 5.3.1 and Figure 5.4.1:

- HT = Horizontal Transmission;
- VT = Vertical Transmission;
- SW = Separating Wall;
- Fa = Façade;
- C = Ceiling;
- PW Small: Partition Wall of the small rooms.

5.1 - Building from the 1930s

As mentioned in Section 4.1, the renovation solution for the building is based on the following elements:

- Façade: lining composed of mineral wool 100 mm with a single layer of 12.5 mm thick plaster boards on independent frame ($\Delta(R_w+C)_{heavy}$ = 14 dB);
- Suspended ceiling: 100 mm cavity filled with 80 mm of mineral wool with a single layer of 12.5 mm thick plaster boards ($\Delta(R_w+C)_{heavy}$ = 15 dB);
- Separating wall: lining composed of 45 mm of mineral wool with a single layer of 12.5 mm thick plaster boards on independent frame ($\Delta(R_w+C)_{heavy}$ = 13 dB).

Based on the results shown in Table 7.1.1 in Annex B and Figure 5.1.1, the following remarks can be drawn:

- The performances expressed with $D_{nT,w}$ + $C_{50\text{-}3150}$ lead to the lowest ISO/TS 19488 acoustic classification;
- The performances expressed with $D_{nT,w}$ + $C_{Indoor40}$ lead to the highest ISO/TS 19488 acoustic classification;
- Qualitel rating yields the highest acoustic classification;
- The lining on both sides of the separating wall increases up to 10 to 12 dB the value of the SNQ for the horizontal transmission; the other treatments (façade + ceiling) boost up to around 4 dB more;

- The lining on both sides of the separating wall has no impact on the vertical transmission; the other treatments (façade + ceiling) improve up to around 5 dB the SNQ;
- The treatments giving the more homogeneous performances (between horizontal and vertical transmission) are the ones made on the separating wall and the ceiling.

Similar behavior is observed based on the loudness evaluation:

- For the horizontal transmission, the lining on both sides of the separating wall decreases the loudness by a factor of about 2.5; when adding the other treatments (façade + ceiling) the loudness is decreased by a factor of 4.8;
- For the vertical transmission, the lining on both sides of the separating wall has no impact on loudness; when adding the other treatments (façade + ceiling) the loudness is decreased by a factor of about 1.5.

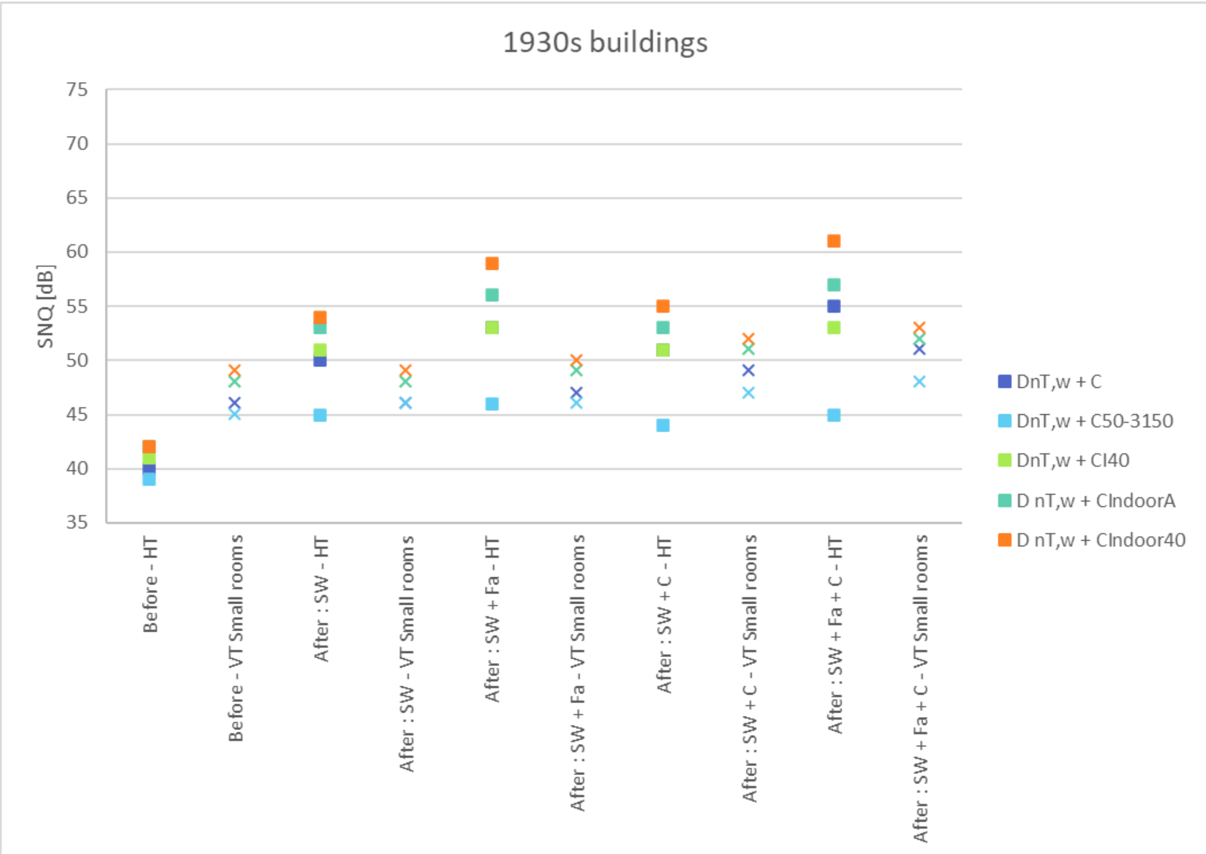


Figure 5.1.1: 1930s building – Step-by-step building improvement – Airborne sound insulation performance.

5.2 - Building from the 1970s

5.2.1 - Concrete based separating wall

As mentioned in Section 4.2.1, the renovation solution for the building is based on the following elements:

- Façade: lining composed of mineral wool 100 mm with a single layer of 12.5 mm thick plaster boards on independent frame ($\Delta(R_w+C)_{heavy}$ = 14 dB);
- Plastic floor covering $\Delta L_w \geq 19$ dB;
- Suspended ceiling : 50 mm cavity filled with 45 mm of mineral wool with a single layer of 12.5 mm thick plaster boards ($\Delta(R_w+C)_{heavy}$ = 13 dB);
- Small rooms partition walls: lining composed of 45 mm of mineral wool with a single layer of 12.5 mm thick plaster boards on independent frame ($\Delta(R_w+C)_{heavy}$ = 13 dB)
- Separating wall on small rooms side: lining composed of 45 mm of mineral wool with a single layer of 12.5 mm thick plaster boards on independent frame ($\Delta(R_w+C)_{heavy}$ = 13 dB)
- Separating wall on large rooms side: lining composed of 100 mm of mineral wool with a single layer of 12.5 mm thick plaster boards on independent frame ($\Delta(R_w+C)_{heavy}$ = 14 dB).

Based on the results shown in Table 7.2.1 in Annex B and Figure 5.2.1, the following remarks can be drawn:

- The performances expressed with $D_{nT,w} + C_{50\text{-}3150}$ lead to the lowest ISO/TS 19488 acoustic classification;
- The performances expressed with $D_{nT,w} + C_{Indoor40}$ lead to the highest ISO/TS 19488 acoustic classification;
- Qualitel rating yields the highest acoustic classification;
- The lining on both sides of the separating wall improves up to 10 to 12 dB the value of the SNQ for the horizontal transmission; the other treatments (façade + ceiling) boost up to around 2 dB more;
- The lining on both sides of the separating wall has no impact on the vertical transmission acoustic performance; the other treatments (façade + ceiling) upgrade up to around 3 dB the SNQ;
- In order to reach the desired acoustic performance (class before renovation + 2), a complementary treatment is necessary on the partition wall of the small rooms. However, it leads to quite inhomogeneous performances for the vertical transmission;

- The lining on the façade has no impact on both the horizontal and the vertical transmission;
- The renovation treatments to meet the desired acoustic class lead to inhomogeneous performances between the horizontal and the vertical transmission.

Similar behavior is observed based on the loudness evaluation:

- For the horizontal transmission, the lining on both sides of the separating wall decreases the loudness by a factor of about 4.2; when adding the other treatments (façade + ceiling) the loudness is decreased by a factor of about 9.3;
- For the vertical transmission, the lining on both sides of the separating wall has no impact on loudness; when adding the other treatments (façade + ceiling) the loudness is decreased by a factor of about 1.3;
- When adding a supplementary lining on the partition wall of the small rooms, the loudness is reduced by a factor of 10 for the horizontal transmission and a factor of 16.6 for the horizontal transmission between small rooms, and a factor of 1.4 for the horizontal transmission between large rooms.

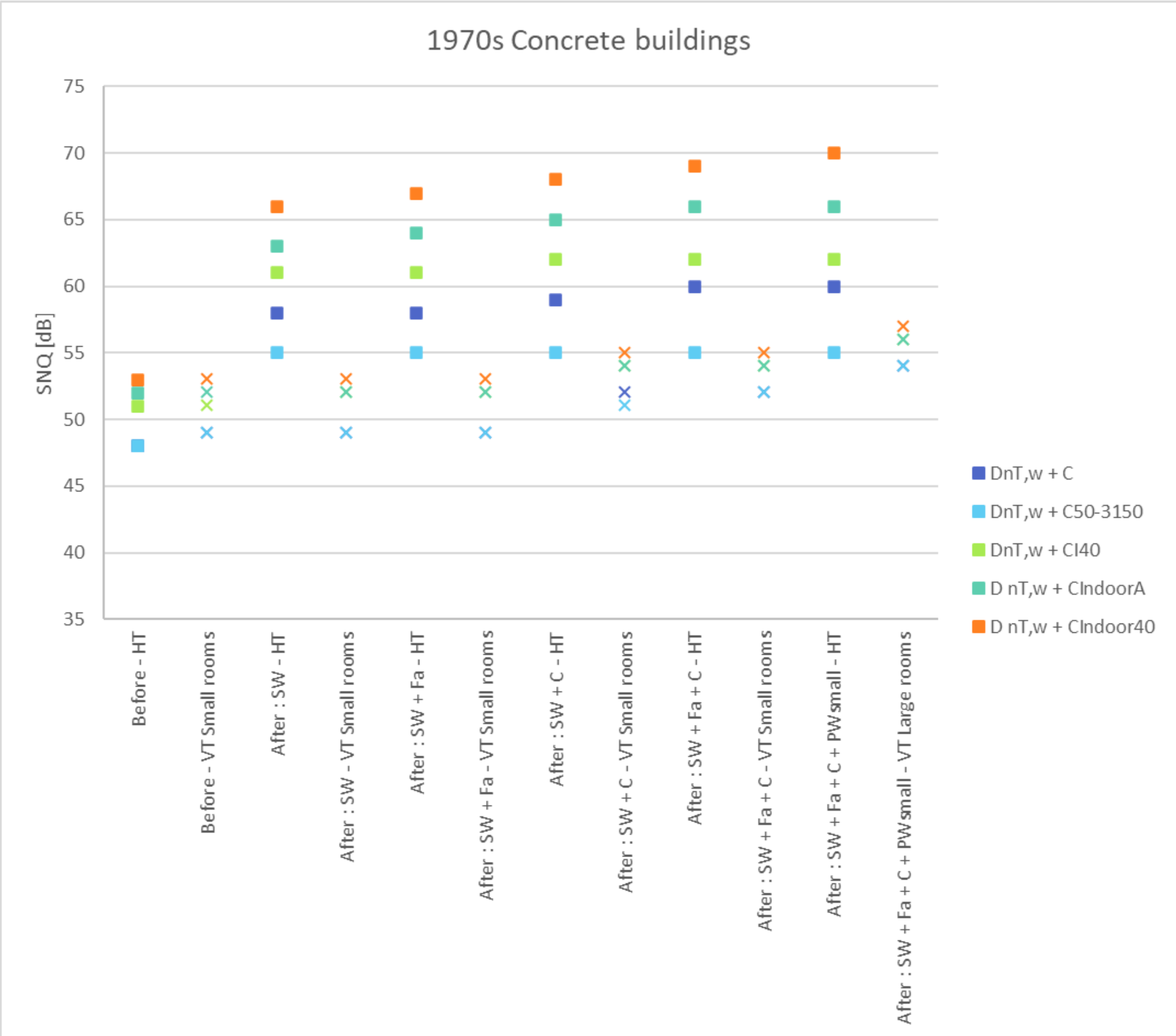


Figure 5.2.1: 1970s building with concrete based separating wall – Step-by-step building improvement – Airborne sound insulation performance in dB.

5.2.2 - Brick based separating wall

As mentioned in Section 4.2.2, the renovation solution for the building is based on the following elements:

- Façade: lining composed of mineral wool 100 mm with a single layer of 12.5 mm thick plaster boards on independent frame ($\Delta(R_w+C)_{heavy}$ = 14 dB);
- Plastic floor covering $\Delta L_w \geq$ 19 dB;
- Suspended ceiling: 50 mm cavity filled with 45 mm of mineral wool with a single layer of 12.5 mm thick plaster boards ($\Delta(R_w+C)_{heavy}$ = 13 dB);

- Separating wall: lining composed of 45 mm of mineral wool with a single layer of 12.5 mm thick plaster boards on independent frame ($\Delta(R_w+C)_{heavy}$ = 13 dB).

Based on the results shown in Table 7.2.6 in Annex B and Figure 5.2.2, the following remarks can be drawn:

- The performances expressed with $D_{nT,w}$ + $C_{50\text{-}3150}$ lead to the lowest ISO/TS 19488 acoustic classification;
- The performances expressed with $D_{nT,w}$ + $C_{Indoor40}$ lead to the highest ISO/TS 19488 acoustic classification;
- Qualitel rating yields the highest acoustic classification;
- The lining on both sides of the separating wall increases up to 15 to 19 dB the value of the SNQ for the horizontal transmission; the other treatments (façade + ceiling) boost up to around 1 dB more;
- The lining on both sides of the separating wall improves only up to 1 dB the value of the SNQ for the vertical transmission; the other treatments (façade + ceiling) ameliorate up to around 4 dB the SNQ;
- The lining on the façade has almost no impact on the acoustic performance for both the horizontal and the vertical transmission;
- The renovation treatments providing the more homogeneous performances (between horizontal and vertical transmission) are the lining on both sides of the separating wall and the suspended ceiling.

Similar behavior is observed based on the loudness evaluation:

- For the horizontal transmission, the lining on both sides of the separating wall decreases the loudness by a factor of about 6.8; when adding the other treatments (façade + ceiling) the loudness is decreased by a factor of about 8;
- For the vertical transmission, the lining on both sides of the separating wall has no impact on loudness; when adding the other treatments (façade + ceiling) the loudness is decreased by a factor of about 1.4.

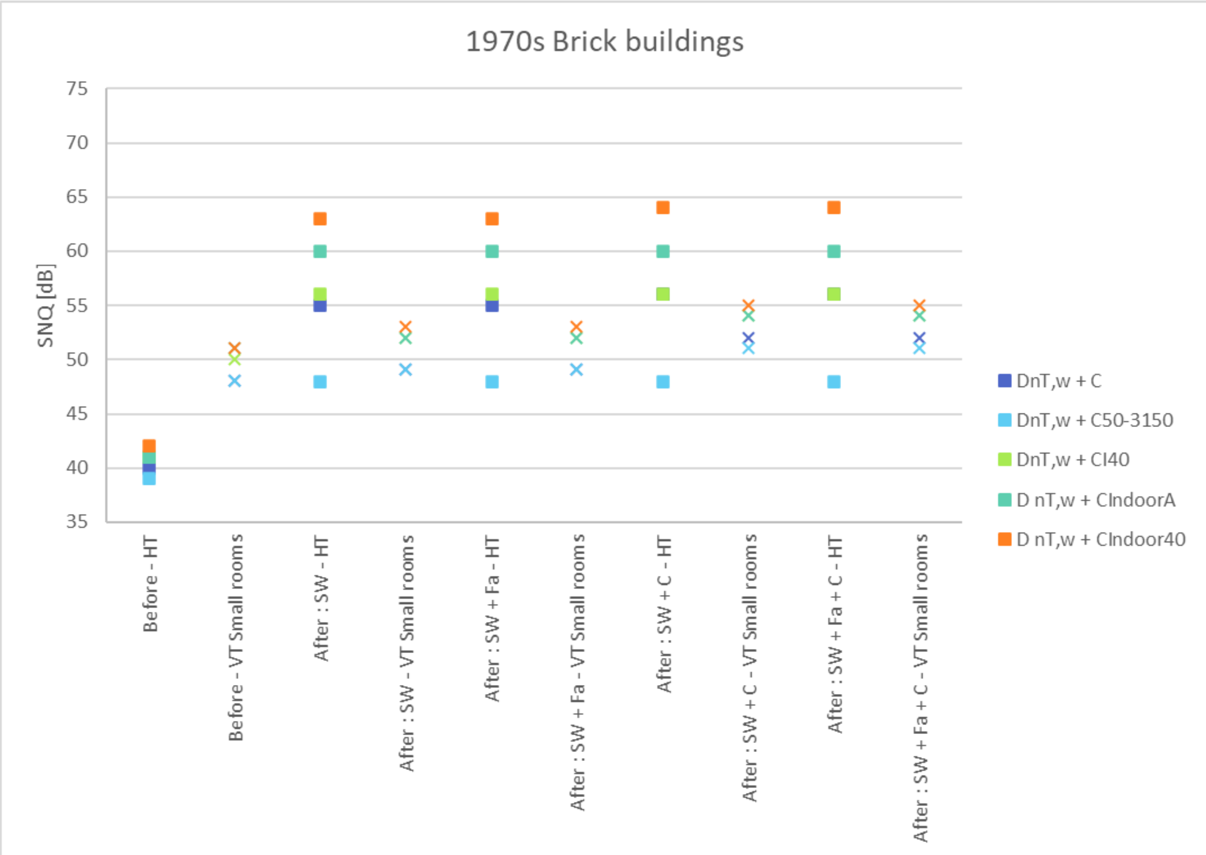


Figure 5.2.2: 1970s building with brick-based separating wall – Step-by-step building improvement – Airborne sound insulation performance in dB.

5.3 - Modern concrete-based building

As mentioned in Section 4.3, the upgrading solution for the building is based on the following elements:

- Façade: lining composed of mineral wool 100 mm with a single layer of 12.5 mm thick plaster boards on independent frame ($\Delta(R_w+C)_{heavy}$ = 14 dB);
- Floating screed 40 mm on mineral 20 mm wool with $\Delta L_w \geq$ 27 dB and $\Delta(R_w+C)_{heavy\ floorl} \geq$ 10 dB;
- Separating wall: lining composed of mineral wool 45 mm with a single layer of 12.5 mm thick plaster boards on independent frame ($\Delta(R_w+C)_{heavy}$ = 13 dB) on small room size and lining composed of mineral wool 100 mm with a single layer of 12.5 mm thick plaster boards on independent frame ($\Delta(R_w+C)_{heavy}$ = 14 dB) on large room size;

Based on the results shown in Table 7.3.1 in Annex B and Figure 5.3.1, the following remarks can be drawn:

- The performances expressed with $D_{nT,w}$ + $C_{50-3150}$ lead to the lowest ISO/TS 19488 acoustic classification
- The performances expressed with $D_{nT,w}$ + $C_{Indoor40}$ lead to the highest ISO/TS 19488 acoustic classification
- Qualitel rating yields the highest acoustic classification
- The lining on both sides of the separating wall increases up to 13 dB the value of the SNQ for the horizontal transmission; the other treatments (façade + floating floor) boost up to around 3 dB more.
- The lining on both sides of the separating wall has no impact on the vertical transmission acoustic performance; the other treatments (façade + floating floor) improve up to around 11 dB the SNQ.
- The lining on the façade increases up to 2 dB the value of the SNQ for the horizontal transmission and 1 dB for the vertical transmission.
- The upgrading treatments providing the more homogeneous acoustic performances (between horizontal and vertical transmission) are the ones applied to the separating wall and the floor.

Similar behavior is observed based on the loudness evaluation:

- For the horizontal transmission, the lining on both sides of the separating wall decreases the loudness by a factor of about 3.7; when adding the other treatments (façade + floating floor) the loudness is decreased by a factor of about 24.7;
- For the vertical transmission, the lining on both sides of the separating wall has no impact on loudness; when adding the other treatments (façade + floating floor) the loudness is decreased by a factor of about 4.8 in average.

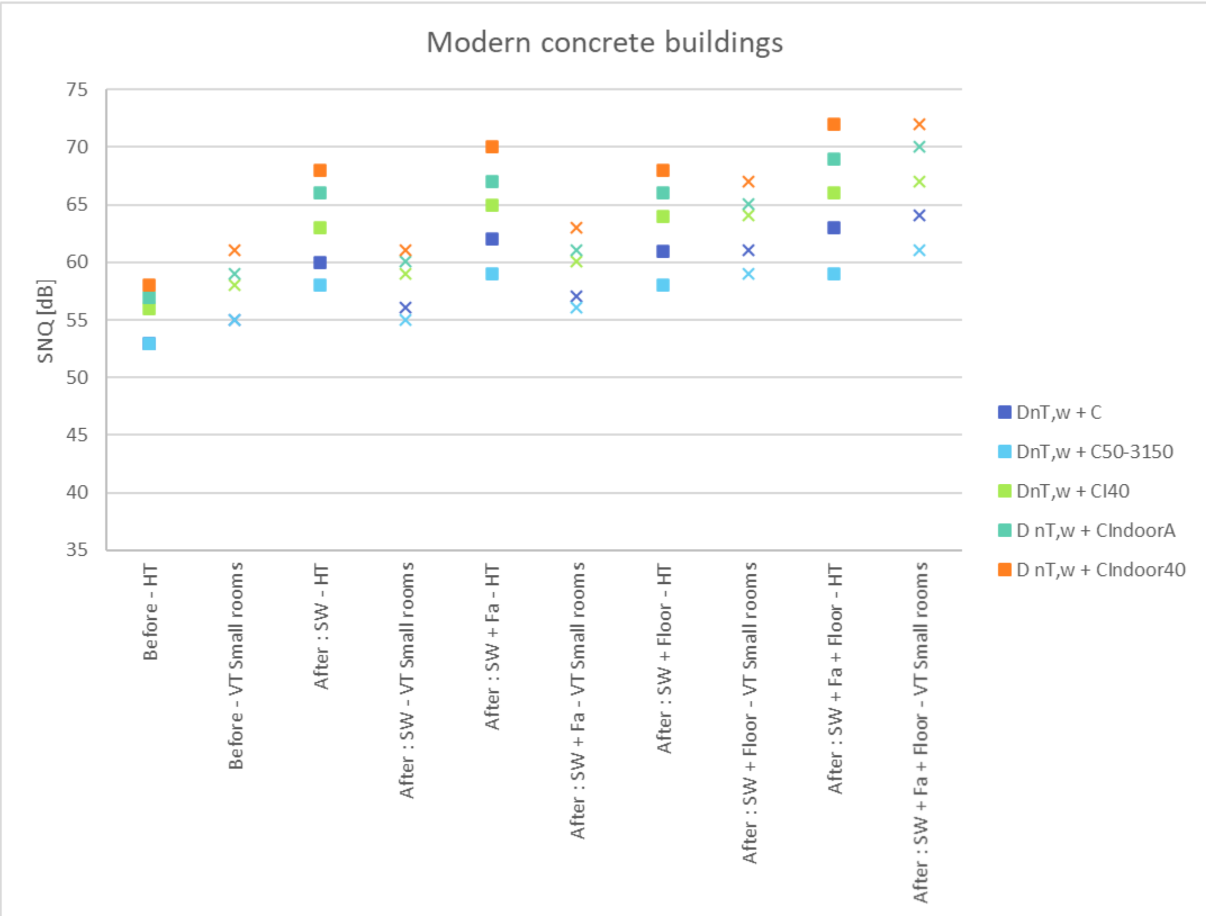


Figure 5.3.1: Modern concrete-based building – Step-by-step building improvement – Airborne sound insulation performance in dB.

5.4 - Modern wood-based building

As mentioned in Section 4.4, the upgrading solution for the building is based on the following elements:

- Separating wall: lining with 100 mm of mineral wool and a double layer of 12.5 mm thick plaster boards on independent frame, on the small room sides;
- Separating wall: lining with 100 mm of mineral wool and a single layer of 12.5 mm thick plaster boards on independent frame, on the large room sides;
- Floating screed 60 mm in thickness on 15 mm of mineral wool $\Delta(R_w+C) \geq 17$ dB;
- Suspended ceiling: 150 mm cavity filled with 130 mm of mineral wool and a double layer of 12.5 mm thick plaster boards.

Based on the results shown in Table 7.4.1 in Annex B and Figure 5.4.1, the following remarks can be drawn:

- The performances expressed with $D_{nT,w}$ + $C_{50\text{-}3150}$ lead to the lowest ISO/TS 19488 acoustic classification
- The performances expressed with $D_{nT,w}$ + $C_{Indoor40}$ lead to the highest ISO/TS 19488 acoustic classification
- Qualitel rating provides the highest acoustic classification
- The lining on both sides of the separating wall increases up to 8 dB the value of the SNQ for the horizontal transmission; the other treatments (floor + ceiling) complement up to around 1 dB more.
- The lining on both sides of the separating wall increases up to 5 dB the value of the SNQ for the vertical transmission; the other treatments (floor + ceiling) boost up to around 6 dB the SNQ.
- The treatment on the floor has a quite small impact (0 to 1 dB).
- The upgrading treatments providing the more homogeneous performances (between horizontal and vertical transmission) are the linings on the separating wall and the suspended ceiling.

Similar behavior is observed based on the loudness evaluation:

- For the horizontal transmission, the lining on both sides of the separating wall decreases the loudness by a factor of about 3.9; when adding the other treatments (façade + floating floor/suspended ceiling) the loudness is decreased by a factor of about 4.8;
- For the vertical transmission, the lining on both sides of the separating wall allows a decrease of the loudness by a factor of 1.9; when adding the other treatments (façade + floating floor/suspended ceiling) the loudness is decreased by a factor of more than 2.3.

Figure 5.4.1: Modern wood-based building – Step-by-step building improvement – Airborne sound insulation performance in dB.

5.5 - Summary

Table 5.5.1 and Table 5.5.2 present a summary in terms of expected improvement for the different buildings considered, with respect to the SNQ and the loudness respectively.

In Table 5.5.1, the notion of "Balance HT/VT" is introduced to the balance in terms of performance between the horizontal and vertical transmission. In the case of the 1970s building with concrete based separating wall, the vertical and horizontal transmission are associated to very different performance levels due to the required classification level improvement; the renovation solution is thus not balanced.

Table 5.5.1: Overview of acoustic improvement with respect to SNQ.

Treatments	Transmission type	1930s	1970s concrete	1970s bricks	Modern concrete	Modern wood
Lining on both side of the separating wall	HT	+10 / 12 dB	+10 / 12 dB	+15 / 19 dB	+13 dB	+8 dB
	VT	0 dB	0 dB	+1dB	0 dB	+5dB
All other treatments	HT	+4 dB more	+2 dB more	+1 dB more	+3 dB more	+1 dB more
	VT	+5 dB	+3 dB	+4 dB more	+11 dB	+6 dB more
Lining on the façade	HT	-	0 dB	0 dB	+2 dB	-
	VT	-	0 dB	0 dB	+1 dB	-
Balance HT/VT	-	SW + Ceiling	None	SW + Ceiling	SW + Floor	SW + Ceiling

Table 5.5.2: Overview of acoustic improvement with respect to loudness.

Treatments	Transmission type	1930s	1970s concrete	1970s bricks	Modern concrete	Modern wood
Lining on both side of the separating wall	HT	÷ 2.5	÷ 4.2	÷ 6.8	÷ 3.7	÷ 3.9
	VT	No impact	No impact	No impact	No impact	÷ 1.9
All other treatments	HT	÷ 4.8	÷ 10.0	÷ 8.0	÷ 24.7	÷ 4.8
	VT	÷ 1.5	÷ 16.6	÷ 1.4	÷ 4.8	÷ 2.3

Finally for the considered buildings, the following remarks apply:

- The performances expressed with $D_{nT,w}$ + $C_{50-3150}$ lead to the lowest ISO/TS 19488 acoustic classification;
- The performances expressed with $D_{nT,w}$ + $C_{Indoor40}$ lead to the highest ISO/TS 19488 acoustic classification;
- Qualitel rating yields the highest acoustic classification.

Furthermore, for the 1970s building with concrete based separating wall, in order to reach the desired acoustic performance (classification improvement of 2 levels after renovation), a complementary acoustic treatment was found necessary on the partition wall of the small rooms. However, this led to unbalanced performance between vertical and horizontal transmission.

For the modern wood-based building, the considered treatment on top of the floor has a quite small impact (0 to 1 dB) on the acoustic performance.

Finally, the classification levels obtained using the new SNQ (i.e., $D_{nT,w}$ + C_{I40}, $D_{nT,w}$ + $C_{IndoorA}$, and $D_{nT,w}$ + $C_{Indoor40}$) are quite close to those obtained with Qualitel classification. The results obtained using the loudness would need more work in order to actually access the loudness value with respect to occupant comfort and propose on this basis an adapted and appropriate acoustic classification.

6 - ANNEXE A – INDEX, CLASSIFICATION AND LOUDNESS

6.1 - Performance index

A reminder the index evaluation $D_{nT,w}+C_{50\text{-}3150}$ is based on the following expression

$$D_{nT,w} + C_{50-3150} = -10\log_{10}\left[\sum 10^{(L_i - D_{nT,i})/10}\right]$$

with L_i given in Table 6.1.1 for the different index for each one-third frequency band *i*.

For the indexes $D_{nT,w}+C_{I40}$, $D_{nT,w}+C_{IndoorA}$, $D_{nT,w}+C_{Indoor40}$, the procedure is similar using the associated L_i data presented in Table 6.1.1.

Table 6.1.1: Tabulated values L_i in dB for performance index evaluation.

Frequency (Hz)	$D_{nT,w} + C_{50\text{-}3150}$	$D_{nT,w} + C_{I40}$	$D_{nT,w} + C_{IndoorA}$	$D_{nT,w} + C_{Indoor40}$
50	-41.0	-49.4	-56.0	-64.3
63	-37.0	-44.7	-50.5	-58.1
80	-34.0	-40.1	-45.3	-52.0
100	-30.0	-36.0	-40.4	-46.4
125	-27.0	-32.2	-35.9	-41.1
160	-24.0	-28.3	-31.7	-35.7
200	-22.0	-25.0	-27.7	-30.9
250	-20.0	-22.0	-23.9	-26.4
315	-18.0	-19.2	-20.4	-22.1
400	-16.0	-16.6	-17.1	-18.0
500	-14.0	-14.7	-14.0	-14.6
630	-13.0	-12.9	-12.7	-12.8
800	-12.0	-11.7	-11.6	-11.6
1000	-11.0	-11.6	-10.8	-11.5
1250	-10.0	-13.4	-10.2	-13.3
1600	-10.0	-14.1	-9.8	-14.0
2000	-10.0	-10.8	-9.6	-10.7
2500	-10.0	-8.1	-9.5	-8.0
3150	-10.0	-7.2	-9.6	-7.1
4000		-8.2	-9.8	-8.1
5000		-11.6	-10.3	-11.5

6.2 - Building classes

Table 6.2.1 to Table 6.2.4 shows the index values to determine the performance class respectively from ISO/TS 19488 using both $D_{nT,w}+C_{50\text{-}3150}$ and $D_{nT,w}+C$, from ISO/TS 19488 either using $D_{nT,w}+C_{50\text{-}3150}$ or $D_{nT,w}+C$, and from Qualitel.

Following note “a” of Table 1 in ISO/TS 19488 Section 5.3, $D_{nT,A}$ = $D_{nT,w}$+C can be used instead of $D_{nT,50}$ = $D_{nT,w}+C_{50-3150}$ by adding 2 dB to the limit value of $D_{nT,50}$ = $D_{nT,w}+C_{50-3150}$. Applying this rule gives Tables 6.2.2 and 6.2.3.

Table 6.2.1: ISO/TS 19488 (Section 5.3, Table 1) based on both $D_{nT,w}$+C and $D_{nT,w}+C_{50-3150}$.

Type of space	F	E	D	C	B	A
Between habitable rooms in a dwelling and rooms outside the dwelling in all directions	$D_{nT,w}$+C ≥ 40 dB	$D_{nT,w}$+C ≥ 44 dB	$D_{nT,w}$+C ≥ 48 dB	$D_{nT,w}$+C ≥ 52 dB	$D_{nT,w}+C_{50-3150}$ ≥ 54 dB	$D_{nT,w}+C_{50-3150}$ ≥ 58 dB

Table 6.2.2: ISO/TS 19488 based only on $D_{nT,w}+C_{50-3150}$.

Type of space	F	E	D	C	B	A
Between habitable rooms in a dwelling and rooms outside the dwelling in all directions	≥ 38 dB	≥ 42 dB	≥ 46 dB	≥ 50 dB	≥ 54 dB	≥ 58 dB

Table 6.2.3: ISO/TS 19488 based only on $D_{nT,w}$+C.

Type of space	F	E	D	C	B	A
Between habitable rooms in a dwelling and rooms outside the dwelling in all directions	≥ 40 dB	≥ 44 dB	≥ 48 dB	≥ 52 dB	≥ 56 dB	≥ 60 dB

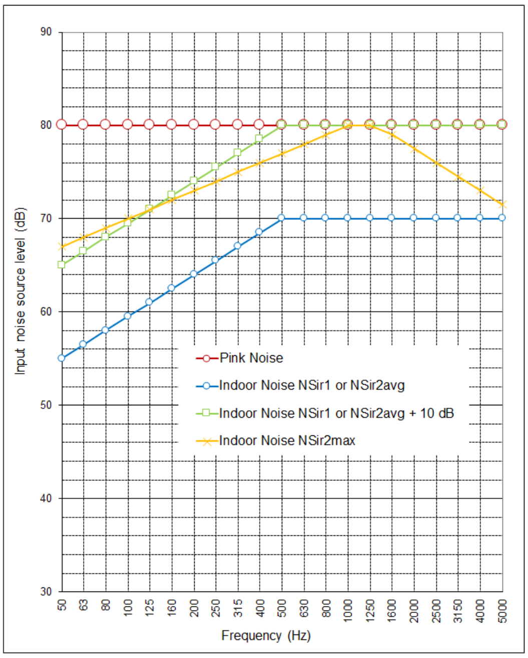
Table 6.2.4: Qualitel rating based on $D_{nT,A}$ = $D_{nT,w}$+C.

Type of space	E	D	C	B	A	A+
Between habitable rooms in a dwelling and rooms from other dwellings	< 43 dB	≥ 43 dB	≥ 48 dB	≥ 53 dB	≥ 58 dB	≥ 63 dB

6.3 - Loudness

The evaluation of the Zwicker loudness is obtained using the independent tool developed to calculate this indicator based on ISO 532-1 and provided by CSTB to Eurima/Eurogypsum in 2023.

The input noise source spectra are given in Figure 6.3.1.



Frequency (Hz)	Pink Noise	Indoor Noise NSir1 or NSir2avg	Indoor Noise NSir1 or NSir2avg	Indoor Noise NSir2max
50	80.0	55.0	55.0	67.0
63	80.0	56.5	56.5	68.0
80	80.0	58.0	58.0	69.0
100	80.0	59.5	59.5	70.0
125	80.0	61.0	61.0	71.0
160	80.0	62.5	62.5	72.0
200	80.0	64.0	64.0	73.0
250	80.0	65.5	65.5	74.0
315	80.0	67.0	67.0	75.0
400	80.0	68.5	68.5	76.0
500	80.0	70.0	70.0	77.0
630	80.0	70.0	70.0	78.0
800	80.0	70.0	70.0	79.0
1000	80.0	70.0	70.0	80.0
1250	80.0	70.0	70.0	80.0
1600	80.0	70.0	70.0	79.0
2000	80.0	70.0	70.0	77.5
2500	80.0	70.0	70.0	76.0
3150	80.0	70.0	70.0	74.5
4000	80.0	70.0	70.0	73.0
5000	80.0	70.0	70.0	71.5
Gain (dB)	-	-	10.0	-

Figure 6.3.1: Input noise source spectra dB for loudness evaluation.

Table 6.3.1: Loudness of the input noise source spectra given in Figure 6.3.1.

Noise source type	Loudness (sone)
Pink noise	103.5288
Indoor Noise NSir1 or NSir2avg	52.4833
Indoor Noise NSir1 or NSir2avg + Gain (10 dB)	96.8890
Indoor Noise NSir2max	79.0273

7 - ANNEXE B –ACOUSTIC PERFORMANCE OF STEP-BY-STEP BUILDING MODIFICATIONS

In this Annex B, intermediary acoustic performance for each renovation step and for the different types of buildings is given. The different treatments applied to the building are described in Section 4.

7.1 - Building from the 1930s

Table 7.1.1: 1930s building – Step-by-step building improvement – Airborne sound insulation performance in dB.

	$D_{nT,w}$ + C	$D_{nT,w}$ + $C_{50\text{-}3150}$	$D_{nT,w}$ + C_{I40}	$D_{nT,w}$ + $C_{IndoorA}$	$D_{nT,w}$ + $C_{Indoor40}$
Before renovation					
Horizontal transmission	40	39	41	42	42
Vertical transmission – Large rooms	47	47	49	49	50
Vertical transmission – Small rooms	46	45	48	48	49
After renovation: with lining on both sides of the separating wall					
Horizontal transmission	50	45	51	53	54
Vertical transmission – Large rooms	47	47	49	49	50
Vertical transmission – Small rooms	46	46	48	48	49
After renovation: with lining on both sides of the separating wall and lining on façade					
Horizontal transmission	53	46	53	56	59
Vertical transmission – Large rooms	48	48	50	50	51
Vertical transmission – Small rooms	47	46	49	49	50
After renovation: with lining on both sides of the separating wall and suspended ceiling					
Horizontal transmission	51	44	51	53	55
Vertical transmission – Large rooms	51	49	52	53	54
Vertical transmission – Small rooms	49	47	51	51	52
After renovation: with lining on both sides of the separating wall and lining on façade and suspended ceiling					
Horizontal transmission	55	45	53	57	61
Vertical transmission – Large rooms	53	49	54	54	55
Vertical transmission – Small rooms	51	48	52	52	53

Table 7.1.2: 1930s building – Step-by-step building improvement – Building class performance.

1930s building	ISO/TS 19488[1]	ISO/TS 19488[2] $D_{nT,w}$ + $C_{50-3150}$ only	ISO/TS 19488[3] $D_{nT,w}$ + C_{I40}	ISO/TS 19488[3] $D_{nT,w}$ + $C_{IndoorA}$	ISO/TS 19488[3] $D_{nT,w}$ + $C_{Indoor40}$	ISO/TS 19488[4] $D_{nT,w}$ + C only	Qualitel[5] $D_{nT,w}$ + C
Before renovation	F	F	F	F	E	F	E
After renovation: with lining on both sides of the separating wall	E	E	D	D	D	E	D
After renovation: with lining on both sides of the separating wall and lining on façade	E	D	D	D	C	E	D
After renovation: with lining on both sides of the separating wall and supported ceiling	D	D	C	C	C	D	D
After renovation: with lining on both sides of the separating wall and lining on façade and supported ceiling	D	E	C	C	C	D	C

[1] See Table 6.2.1 in Annex A.
[2] See Table 6.2.2 in Annex A.
[3] ISO/TS 19488 does not provide a classification based on this index, thus the classification proposed here is based on the same values that for $D_{nT,w}$+$C_{50-3150}$ given in Table 6.2.3 in Annex A.
[4] See Table 6.2.3 in Annex A.
[5] See Table 6.2.4 in Annex A.

Table 7.1.3: 1930s building – Step-by-step building improvement – Loudness evaluation in sone.

Input noise source	Pink noise	Indoor Noise NSir1 or NSir2avg	Indoor Noise NSir1 or NSir2avg + 10 dB	Indoor Noise NSir2max
Before renovation				
Horizontal transmission	8.2601	3.1491	7.0395	5.8257
Vertical transmission – Large rooms	4.4861	1.3375	3.6466	3.0456
Vertical transmission – Small rooms	5.0731	1.6083	4.1783	3.4934
After renovation: with lining on both sides of the separating wall				
Horizontal transmission	4.5626	0.9221	2.9605	2.5006
Vertical transmission – Large rooms	4.418	1.2963	3.5669	2.985
Vertical transmission – Small rooms	4.9418	1.5224	4.0204	3.3745
After renovation: with lining on both sides of the separating wall and lining on façade				
Horizontal transmission	3.5018	0.5006	1.8727	1.7379
Vertical transmission – Large rooms	4.0928	1.1533	3.2682	2.752
Vertical transmission – Small rooms	4.6059	1.3682	3.7091	3.1276
After renovation: with lining on both sides of the separating wall and suspended ceiling				
Horizontal transmission	4.7003	0.8692	2.8645	2.4346
Vertical transmission – Large rooms	3.8441	0.8854	2.8068	2.3339
Vertical transmission – Small rooms	4.4526	1.1387	3.3226	2.8026
After renovation: With lining on both sides of the separating wall and lining on façade and suspended ceiling				
Horizontal transmission	3.5092	0.3769	1.5473	1.4861
Vertical transmission – Large rooms	3.4245	0.7018	2.4159	2.027
Vertical transmission – Small rooms	4.0456	0.9537	2.9454	2.5058

Table 7.1.4: 1930s building – Intermediary building improvement relative to lining on separating wall – Airborne sound insulation performance in dB.

	$D_{nT,w}$ + C	$D_{nT,w}$ + $C_{50\text{-}3150}$	$D_{nT,w}$ + C_{I40}	$D_{nT,w}$ + $C_{IndoorA}$	$D_{nT,w}$ + $C_{Indoor40}$
Before renovation					
Horizontal transmission	40	39	41	42	42
Vertical transmission – Large rooms	47	47	49	49	50
Vertical transmission – Small rooms	46	45	48	48	49
After renovation: with lining on small room side of the separating wall					
Horizontal transmission	46	45	48	48	49
Vertical transmission – Large rooms	47	47	49	49	50
Vertical transmission – Small rooms	46	46	48	48	49
After renovation: with lining on large room side of the separating wall					
Horizontal transmission	48	46	50	51	52
Vertical transmission – Large rooms	47	47	49	49	50
Vertical transmission – Small rooms	46	45	48	48	49
After renovation: with lining on both sides of the separating wall					
Horizontal transmission	50	45	51	53	54
Vertical transmission – Large rooms	47	47	49	49	50
Vertical transmission – Small rooms	46	46	48	48	49

Table 7.1.5: 1930s building – Intermediary building improvement relative to lining on separating wall – Loudness evaluation in sone.

Input noise source	Pink noise	Indoor Noise NSir1 or NSir2avg	Indoor Noise NSir1 or NSir2avg + 10 dB	Indoor Noise NSir2max
Before renovation				
Horizontal transmission	8.2601	3.1491	7.0395	5.8257
Vertical transmission – Large rooms	4.4861	1.3375	3.6466	3.0456
Vertical transmission – Small rooms	5.0731	1.6083	4.1783	3.4934
After renovation: with lining on small room side of the separating wall				
Horizontal transmission	5.0731	1.6083	4.1783	3.4934
Vertical transmission – Large rooms	4.4861	1.3375	3.6466	3.0456
Vertical transmission – Small rooms	4.9418	1.5224	4.0204	3.3745
After renovation: with lining on large room side of the separating wall				
Horizontal transmission	4.7958	1.2606	3.5823	2.9593
Vertical transmission – Large rooms	4.418	1.2963	3.5669	2.985
Vertical transmission – Small rooms	5.0731	1.6083	4.1783	3.4934
After renovation: with lining on both sides of the separating wall				
Horizontal transmission	4.5626	0.9221	2.9605	2.5006
Vertical transmission – Large rooms	4.418	1.2963	3.5669	2.985
Vertical transmission – Small rooms	4.9418	1.5224	4.0204	3.3745

7.2 - Building from the 1970s

7.2.1 - Concrete based separating wall

Table 7.2.1: 1970s building with concrete based separating wall – Step-by-step building improvement – Airborne sound insulation performance in dB.

	$D_{nT,w}$ + C	$D_{nT,w}$ + $C_{50\text{-}3150}$	$D_{nT,w}$ + C_{I40}	$D_{nT,w}$ + $C_{IndoorA}$	$D_{nT,w}$ + $C_{Indoor40}$
Before renovation					
Horizontal transmission	48	48	51	52	53
Vertical transmission – Large rooms	51	50	53	53	54
Vertical transmission – Small rooms	49	49	51	52	53
After renovation: with lining on both sides of the separating wall					
Horizontal transmission	58	55	61	63	66
Vertical transmission – Large rooms	51	51	53	53	54
Vertical transmission – Small rooms	49	49	52	52	53
After renovation: with lining on both sides of the separating wall and lining on façade					
Horizontal transmission	58	55	61	64	67
Vertical transmission – Large rooms	51	51	53	54	55
Vertical transmission – Small rooms	49	49	52	52	53
After renovation: with lining on both sides of the separating wall and suspended ceiling					
Horizontal transmission	59	55	62	65	68
Vertical transmission – Large rooms	54	53	56	56	57
Vertical transmission – Small rooms	52	51	54	54	55
After renovation: with lining on both sides of the separating wall and lining on façade and suspended ceiling					
Horizontal transmission	60	55	62	66	69
Vertical transmission – Large rooms	54	54	56	56	57
Vertical transmission – Small rooms	52	52	54	54	55
After renovation: with lining on both sides of the separating wall and lining on façade, lining on partition walls in small rooms and suspended ceiling					
Horizontal transmission	60	55	62	66	70
Vertical transmission – Large rooms	54	54	56	56	57
Vertical transmission – Small rooms	61	56	64	68	74

Table 7.2.2: 1970s building with concrete based separating wall – Step-by-step building improvement – Building class performance.

	ISO/TS 19488[1]	ISO/TS 19488[2] $D_{nT,w} + C_{50\text{-}3150}$ only	ISO/TS 19488[3] $D_{nT,w} + C_{I40}$	ISO/TS 19488[3] $D_{nT,w} + C_{IndoorA}$	ISO/TS 19488[3] $D_{nT,w} + C_{Indoor40}$	ISO/TS 19488[4] $D_{nT,w}$ + C only	Qualitel[5] $D_{nT,w}$ + C
Before renovation	D	D	D	C	C	D	C
After renovation: with lining on both sides of the separating wall	D	D	D	C	C	D	B
After renovation: with lining on both sides of the separating wall and lining on façade	D	D	D	C	C	D	B
After renovation: with lining on both sides of the separating wall and supported ceiling	C	C	C	B	B	C	B
After renovation: with lining on both sides of the separating wall and lining on façade and supported ceiling	C	C	C	B	B	C	B
After renovation: with lining on both sides of the separating wall and lining on façade, lining on partition walls in small rooms and supported ceiling	B	B	B	B	B	C	B

[1] See Table 6.2.1 in Annex A.
[2] See Table 6.2.2 in Annex A.
[3] ISO/TS 19488 does not provide a classification based on this index, thus the classification proposed here is based on the same values that for $D_{nT,w}+C_{50\text{-}3150}$ given in Table 6.2.3 in Annex A.
[4] See Table 6.2.3 in Annex A.
[5] See Table 6.2.4 in Annex A.

Table 7.2.3: 1970s building with concrete based separating wall – Step-by-step building improvement – Loudness evaluation in sone.

Input noise source	Pink noise	Indoor Noise NSir1 or NSir2avg	Indoor Noise NSir1 or NSir2avg + 10 dB	Indoor Noise NSir2max
Before renovation				
Horizontal transmission	3.5567	0.9350	2.7595	2.3418
Vertical transmission – Large rooms	3.1577	0.8166	2.5389	2.0972
Vertical transmission – Small rooms	3.6441	1.0245	2.9742	2.4659
After renovation: with lining on both sides of the separating wall				
Horizontal transmission	1.5267	0.1216	0.7941	0.7182
Vertical transmission – Large rooms	3.1382	0.8093	2.5246	2.0838
Vertical transmission – Small rooms	3.638	1.0019	2.944	2.4418
After renovation: with lining on both sides of the separating wall and lining on façade				
Horizontal transmission	1.438	0.0949	0.713	0.6467
Vertical transmission – Large rooms	3.1003	0.7953	2.4975	2.0573
Vertical transmission – Small rooms	3.6042	0.9894	2.9207	2.4193
After renovation: with lining on both sides of the separating wall and suspended ceiling				
Horizontal transmission	1.3881	0.0675	0.6237	0.5726
Vertical transmission – Large rooms	2.5495	0.5191	1.9552	1.5856
Vertical transmission – Small rooms	3.0995	0.7226	2.4173	1.9804
After renovation: with lining on both sides of the separating wall and lining on façade and suspended ceiling				
Horizontal transmission	1.2819	0.0392	0.5074	0.4724
Vertical transmission – Large rooms	2.5016	0.504	1.9208	1.5532
Vertical transmission – Small rooms	3.0566	0.7083	2.3874	1.9519
After renovation: with lining on both sides of the separating wall and lining on façade, lining on partition walls in small rooms and suspended ceiling				
Horizontal transmission	1.2947	0.0351	0.4947	0.4637
Vertical transmission – Large rooms	2.5016	0.504	1.9208	1.5532
Vertical transmission – Small rooms	1.1084	0.0227	0.2968	0.3137

Table 7.2.4: 1970s building with concrete based separating wall – Intermediary building improvement relative to lining on separating wall – Airborne sound insulation performance in dB.

	$D_{nT,w}$ + C	$D_{nT,w}$ + $C_{50\text{-}3150}$	$D_{nT,w}$ + C_{I40}	$D_{nT,w}$ + $C_{IndoorA}$	$D_{nT,w}$ + $C_{Indoor40}$
Before renovation					
Horizontal transmission	48	48	51	52	53
Vertical transmission – Large rooms	51	50	53	53	54
Vertical transmission – Small rooms	49	49	51	52	53
After renovation: with lining on small room side of the separating wall					
Horizontal transmission	52	51	54	55	56
Vertical transmission – Large rooms	51	50	53	53	54
Vertical transmission – Small rooms	49	49	52	52	53
After renovation: with lining on large room side of the separating wall					
Horizontal transmission	55	54	59	61	63
Vertical transmission – Large rooms	51	51	53	53	54
Vertical transmission – Small rooms	49	49	51	52	53
After renovation: with lining on both sides of the separating wall					
Horizontal transmission	58	55	61	63	66
Vertical transmission – Large rooms	51	51	53	53	54
Vertical transmission – Small rooms	49	49	52	52	53

Table 7.2.5: 1970s building with concrete based separating wall – Intermediary building improvement relative to lining on separating wall – Loudness evaluation in sone.

Input noise source	Pink noise	Indoor Noise NSir1 or NSir2avg	Indoor Noise NSir1 or NSir2avg + 10 dB	Indoor Noise NSir2max
Before renovation				
Horizontal transmission	3.5567	0.9350	2.7595	2.3418
Vertical transmission – Large rooms	3.1577	0.8166	2.5389	2.0972
Vertical transmission – Small rooms	3.6441	1.0245	2.9742	2.4659
After renovation: with lining on small room side of the separating wall				
Horizontal transmission	2.9664	0.6278	2.1765	1.8395
Vertical transmission – Large rooms	3.1577	0.8166	2.5389	2.0972
Vertical transmission – Small rooms	3.638	1.0019	2.944	2.4418
After renovation: with lining on large room side of the separating wall				
Horizontal transmission	1.7601	0.2377	1.0893	0.9596
Vertical transmission – Large rooms	3.1382	0.8093	2.5246	2.0838
Vertical transmission – Small rooms	3.6441	1.0245	2.9742	2.4659
After renovation: with lining on both sides of the separating wall				
Horizontal transmission	1.5267	0.1216	0.7941	0.7182
Vertical transmission – Large rooms	3.1382	0.8093	2.5246	2.0838
Vertical transmission – Small rooms	3.638	1.0019	2.944	2.4418

7.2.2 - Brick based separating wall

Table 7.2.6: 1970s building with brick-based separating wall separating wall – Step-by-step building improvement – Airborne sound insulation performance in dB.

	$D_{nT,w}$ + C	$D_{nT,w}$ + $C_{50\text{-}3150}$	$D_{nT,w}$ + C_{I40}	$D_{nT,w}$ + $C_{IndoorA}$	$D_{nT,w}$ + $C_{Indoor40}$
Before renovation					
Horizontal transmission	40	39	41	41	42
Vertical transmission – Large rooms	50	50	53	53	54
Vertical transmission – Small rooms	48	48	50	51	51
After renovation: with lining on both sides of the separating wall					
Horizontal transmission	55	48	56	60	63
Vertical transmission – Large rooms	51	50	53	53	54
Vertical transmission – Small rooms	49	49	52	52	53
After renovation: with lining on both sides of the separating wall and lining on façade					
Horizontal transmission	55	48	56	60	63
Vertical transmission – Large rooms	51	51	53	54	55
Vertical transmission – Small rooms	49	49	52	52	53
After renovation: with lining on both sides of the separating wall and suspended ceiling					
Horizontal transmission	56	48	56	60	64
Vertical transmission – Large rooms	54	53	56	56	57
Vertical transmission – Small rooms	52	51	54	54	55
After renovation: with lining on both sides of the separating wall and lining on façade and suspended ceiling					
Horizontal transmission	56	48	56	60	64
Vertical transmission – Large rooms	54	54	56	56	57
Vertical transmission – Small rooms	52	51	54	54	55

Table 7.2.7: 1970s building with brick based separating wall – Step-by-step building improvement – Building class performance.

	ISO/TS 19488[1]	ISO/TS 19488[2] $D_{nT,w}$ + $C_{50-3150}$ only	ISO/TS 19488[3] $D_{nT,w}$ + C_{I40}	ISO/TS 19488[3] $D_{nT,w}$ + $C_{IndoorA}$	ISO/TS 19488[3] $D_{nT,w}$ + $C_{Indoor40}$	ISO/TS 19488[4] $D_{nT,w}$ + C only	Qualitel[5] $D_{nT,w}$ + C
Before renovation	F	F	F	F	F	F	E
With lining on both sides of the separating wall	D	D	C	C	C	D	C
With lining on both sides of the separating wall and lining on façade	D	D	C	C	C	D	C
With lining on both sides of the separating wall and supported ceiling	C	D	B	B	B	C	C
After renovation: with lining on both sides of the separating wall and lining on façade and supported ceiling	C	D	B	B	B	C	C

[1] See Table 6.2.1 in Annex A.
[2] See Table 6.2.2 in Annex A.
[3] ISO/TS 19488 does not provide a classification based on this index, thus the classification proposed here is based on the same values that for $D_{nT,w}$+$C_{50-3150}$ given in Table 6.2.3 in Annex A.
[4] See Table 6.2.3 in Annex A.
[5] See Table 6.2.4 in Annex A.

Table 7.2.8: 1970s building with brick based separating wall – Step-by-step building improvement – Loudness evaluation in sone.

Input noise source	Pink noise	Indoor Noise NSir1 or NSir2avg	Indoor Noise NSir1 or NSir2avg + 10 dB	Indoor Noise NSir2max
Before renovation				
Horizontal transmission	7.9320	3.1054	6.9218	5.7294
Vertical transmission – Large rooms	3.3124	0.8844	2.6849	2.2089
Vertical transmission – Small rooms	3.9690	1.1731	3.2792	2.7085
After renovation: with lining on both sides of the separating wall				
Horizontal transmission	2.4335	0.2494	1.145	1.0921
Vertical transmission – Large rooms	3.1889	0.8069	2.5327	2.0955
Vertical transmission – Small rooms	3.7139	1.0037	2.9644	2.4652
After renovation: with lining on both sides of the separating wall and lining on façade				
Horizontal transmission	2.4028	0.2336	1.1102	1.0642
Vertical transmission – Large rooms	3.1542	0.7938	2.5076	2.0711
Vertical transmission – Small rooms	3.6776	0.9901	2.939	2.4411
After renovation: with lining on both sides of the separating wall and suspended ceiling				
Horizontal transmission	2.3707	0.2127	1.0632	1.0291
Vertical transmission – Large rooms	2.5639	0.5246	1.9638	1.5891
Vertical transmission – Small rooms	3.1423	0.7314	2.439	1.998
After renovation (With lining on both sides of the separating wall and lining on façade and suspended ceiling)				
Horizontal transmission	2.3336	0.1939	1.0185	0.9933
Vertical transmission – Large rooms	2.5126	0.5089	1.9271	1.5547
Vertical transmission – Small rooms	3.0979	0.7161	2.4058	1.9657

Table 7.2.9: 1970s building with brick based separating wall – Intermediary building improvement relative to lining on separating wall – Airborne sound insulation performance in dB.

	$D_{nT,w}$ + C	$D_{nT,w}$ + $C_{50\text{-}3150}$	$D_{nT,w}$ + C_{I40}	$D_{nT,w}$ + $C_{IndoorA}$	$D_{nT,w}$ + $C_{Indoor40}$
Before renovation					
Horizontal transmission	40	39	41	41	42
Vertical transmission – Large rooms	50	50	53	53	54
Vertical transmission – Small rooms	48	48	50	51	51
After renovation: with lining on small room side of the separating wall					
Horizontal transmission	44	44	46	46	47
Vertical transmission – Large rooms	50	50	53	53	54
Vertical transmission – Small rooms	49	49	52	52	53
After renovation: with lining on large room side of the separating wall					
Horizontal transmission	53	50	55	57	59
Vertical transmission – Large rooms	51	50	53	53	54
Vertical transmission – Small rooms	48	48	50	51	51
After renovation: with lining on both sides of the separating wall					
Horizontal transmission	55	48	56	60	63
Vertical transmission – Large rooms	51	50	53	53	54
Vertical transmission – Small rooms	49	49	52	52	53

Table 7.2.10: 1970s building with brick based separating wall – Intermediary building improvement relative to lining on separating wall – Loudness evaluation in sone.

Input noise source	Pink noise	Indoor Noise NSir1 or NSir2avg	Indoor Noise NSir1 or NSir2avg + 10 dB	Indoor Noise NSir2max
Before renovation				
Horizontal transmission	7.9320	3.1054	6.9218	5.7294
Vertical transmission – Large rooms	3.3124	0.8844	2.6849	2.2089
Vertical transmission – Small rooms	3.9690	1.1731	3.2792	2.7085
After renovation: with lining on small room side of the separating wall				
Horizontal transmission	5.8247	1.9429	4.8494	4.0077
Vertical transmission – Large rooms	3.3124	0.8844	2.6849	2.2089
Vertical transmission – Small rooms	3.7139	1.0037	2.9644	2.4652
After renovation: with lining on large room side of the separating wall				
Horizontal transmission	2.6222	0.4269	1.6593	1.4162
Vertical transmission – Large rooms	3.1889	0.8069	2.5327	2.0955
Vertical transmission – Small rooms	3.969	1.1731	3.2792	2.7085
After renovation: with lining on both sides of the separating wall				
Horizontal transmission	2.4335	0.2494	1.145	1.0921
Vertical transmission – Large rooms	3.1889	0.8069	2.5327	2.0955
Vertical transmission – Small rooms	3.7139	1.0037	2.9644	2.4652

7.3 - Modern concrete-based building

Table 7.3.1: Modern concrete-based building – Step-by-step building improvement – Airborne sound insulation performance in dB.

	$D_{nT,w}$ + C	$D_{nT,w}$ + $C_{50-3150}$	$D_{nT,w}$ + C_{I40}	$D_{nT,w}$ + $C_{IndoorA}$	$D_{nT,w}$ + $C_{Indoor40}$
Before upgrade					
Horizontal transmission	53	53	56	57	58
Vertical transmission – Large rooms	56	56	59	60	61
Vertical transmission – Small rooms	55	55	58	59	61
After upgrade: with lining on both sides of the separating wall					
Horizontal transmission	60	58	63	66	68
Vertical transmission – Large rooms	56	56	59	60	62
Vertical transmission – Small rooms	56	55	59	60	61
After upgrade: with lining on both sides of the separating wall and lining on façade					
Horizontal transmission	62	59	65	67	70
Vertical transmission – Large rooms	57	57	60	61	63
Vertical transmission – Small rooms	57	56	60	61	63
After upgrade: with lining on both sides of the separating wall and floating floor					
Horizontal transmission	61	58	64	66	68
Vertical transmission – Large rooms	62	60	65	67	68
Vertical transmission – Small rooms	61	59	64	65	67
After upgrade: with lining on both sides of the separating wall and lining on façade and floating floor					
Horizontal transmission	63	59	66	69	72
Vertical transmission – Large rooms	65	62	68	71	73
Vertical transmission – Small rooms	64	61	67	70	72

Table 7.3.2: Modern concrete-based building – Step-by-step building improvement

Building class performance.

	ISO/TS 19488[1]	ISO/TS 19488[2] $D_{nT,w}$ + $C_{50\text{-}3150}$ only	ISO/TS 19488[3] $D_{nT,w}$ + C_{I40}	ISO/TS 19488[3] $D_{nT,w}$ + $C_{IndoorA}$	ISO/TS 19488[3] $D_{nT,w}$ + $C_{Indoor40}$	ISO/TS 19488[4] $D_{nT,w}$ + C only	Qualitel[5] $D_{nT,w}$ + C
Before upgrade	C	C	C	B	C	C	B
After upgrade: with lining on both sides of the separating wall	B	B	A	A	A	B	B
After upgrade: with lining on both sides of the separating wall and lining on façade	B	B	A	A	A	B	B
After upgrade: with lining on both sides of the separating wall and floating floor	A	A	A	A	A	A	A
After upgrade: with lining on both sides of the separating wall and lining on façade and floating floor	A	A	A	A	A	A	A+

[1] See Table 6.2.1 in Annex A.
[2] See Table 6.2.2 in Annex A.
[3] ISO/TS 19488 does not provide a classification based on this index, thus the classification proposed here is based on the same values that for $D_{nT,w}$+$C_{50\text{-}3150}$ given in Table 6.2.3 in Annex A.
[4] See Table 6.2.3 in Annex A.
[5] See Table 6.2.4 in Annex A.

Table 7.3.3: Modern concrete-based building – Step-by-step building improvement – Loudness evaluation in sone.

Input noise source	Pink noise	Indoor Noise NSir1 or NSir2avg	Indoor Noise NSir1 or NSir2avg + 10 dB	Indoor Noise NSir2max
Before upgrade				
Horizontal transmission	2.2735	0.4585	1.6501	1.4081
Vertical transmission – Large rooms	1.7040	0.2728	1.1975	1.0017
Vertical transmission – Small rooms	1.8517	0.3110	1.3129	1.0964
After upgrade: with lining on both sides of the separating wall				
Horizontal transmission	1.1573	0.0641	0.5809	0.51
Vertical transmission – Large rooms	1.6673	0.2598	1.1654	0.9734
Vertical transmission – Small rooms	1.8008	0.2801	1.2436	1.0389
After upgrade: with lining on both sides of the separating wall and lining on façade				
Horizontal transmission	0.9757	0.0229	0.4226	0.3714
Vertical transmission – Large rooms	1.5195	0.2103	1.0379	0.8609
Vertical transmission – Small rooms	1.6177	0.217	1.0848	0.8983
After upgrade: with lining on both sides of the separating wall and floating floor				
Horizontal transmission	1.1078	0.0447	0.5173	0.455
Vertical transmission – Large rooms	0.9554	0.0391	0.496	0.4041
Vertical transmission – Small rooms	1.1368	0.0627	0.619	0.501
After upgrade: with lining on both sides of the separating wall and lining on façade and floating floor				
Horizontal transmission	0.9083	0.0053	0.3298	0.2926
Vertical transmission – Large rooms	0.6101	0.0000	0.1830	0.1483
Vertical transmission – Small rooms	0.7546	0.0000	0.2635	0.2040

Table 7.3.4: Modern concrete-based building – Intermediary building improvement relative to lining on separating wall – Airborne sound insulation performance in dB.

	$D_{nT,w}$ + C	$D_{nT,w}$ + $C_{50-3150}$	$D_{nT,w}$ + C_{I40}	$D_{nT,w}$ + $C_{IndoorA}$	$D_{nT,w}$ + $C_{Indoor40}$
Before upgrade					
Horizontal transmission	53	53	56	57	58
Vertical transmission – Large rooms	56	56	59	60	61
Vertical transmission – Small rooms	55	55	58	59	61
After upgrade: with lining on small room side of the separating wall					
Horizontal transmission	57	56	61	63	64
Vertical transmission – Large rooms	56	56	59	60	61
Vertical transmission – Small rooms	56	55	59	60	61
After upgrade: with lining on large room side of the separating wall					
Horizontal transmission	57	57	61	63	65
Vertical transmission – Large rooms	56	56	59	60	62
Vertical transmission – Small rooms	55	55	58	59	61
After upgrade: with lining on both sides of the separating wall					
Horizontal transmission	60	58	63	66	68
Vertical transmission – Large rooms	56	56	59	60	62
Vertical transmission – Small rooms	56	55	59	60	61

Table 7.3.5: Modern concrete-based building – Intermediary building improvement relative to lining on separating wall – Loudness evaluation in sone.

Input noise source	Pink noise	Indoor Noise NSir1 or NSir2avg	Indoor Noise NSir1 or NSir2avg + 10 dB	Indoor Noise NSir2max
Before upgrade				
Horizontal transmission	2.2735	0.4585	1.6501	1.4081
Vertical transmission – Large rooms	1.7040	0.2728	1.1975	1.0017
Vertical transmission – Small rooms	1.8517	0.3110	1.3129	1.0964
After upgrade: with lining on small room side of the separating wall				
Horizontal transmission	1.4931	0.1559	0.8733	0.7622
Vertical transmission – Large rooms	1.704	0.2728	1.1975	1.0017
Vertical transmission – Small rooms	1.8008	0.2801	1.2436	1.0389
After upgrade: with lining on large room side of the separating wall				
Horizontal transmission	1.3641	0.1477	0.8159	0.71
Vertical transmission – Large rooms	1.6673	0.2598	1.1654	0.9734
Vertical transmission – Small rooms	1.8517	0.311	1.3129	1.0964
After upgrade: with lining on both sides of the separating wall				
Horizontal transmission	1.1573	0.0641	0.5809	0.51
Vertical transmission – Large rooms	1.6673	0.2598	1.1654	0.9734
Vertical transmission – Small rooms	1.8008	0.2801	1.2436	1.0389

7.4 - Modern wood-based building

Table 7.4.1: Modern wood-based building – Step-by-step building improvement – Airborne sound insulation performance in dB.

	$D_{nT,w}$ + C	$D_{nT,w}$ + $C_{50-3150}$	$D_{nT,w}$ + C_{I40}	$D_{nT,w}$ + $C_{IndoorA}$	$D_{nT,w}$ + $C_{Indoor40}$
Before upgrade					
Horizontal transmission	53	50	56	58	59
Vertical transmission – Large rooms	54	54	56	56	56
Vertical transmission – Small rooms	53	52	54	54	55
After upgrade: with lining on both sides of the separating wall					
Horizontal transmission	61	56	62	64	65
Vertical transmission – Large rooms	58	57	60	61	61
Vertical transmission – Small rooms	57	56	59	59	60
After upgrade: with lining on both sides of the separating wall and floating floor					
Horizontal transmission	61	56	62	64	65
Vertical transmission – Large rooms	58	57	61	62	62
Vertical transmission – Small rooms	57	56	59	60	61
After upgrade: with lining on both sides of the separating wall and suspended ceiling					
Horizontal transmission	62	59	63	65	65
Vertical transmission – Large rooms	59	59	61	61	62
Vertical transmission – Small rooms	58	57	59	60	60
After upgrade: with lining on both sides of the separating wall, floating floor and suspended ceiling					
Horizontal transmission	62	59	63	65	65
Vertical transmission – Large rooms	60	59	62	62	62
Vertical transmission – Small rooms	58	58	60	60	61

Table 7.4.2: Modern wood-based building – Step-by-step building improvement

Building class performance.

	ISO/TS 19488[1]	ISO/TS 19488[2] $D_{nT,w}$ + $C_{50\text{-}3150}$ only	ISO/TS 19488[3] $D_{nT,w}$ + C_{I40}	ISO/TS 19488[3] $D_{nT,w}$ + $C_{IndoorA}$	ISO/TS 19488[3] $D_{nT,w}$ + $C_{Indoor40}$	ISO/TS 19488[4] $D_{nT,w}$ + C only	Qualitel[5] $D_{nT,w}$ + C
Before upgrade	C	C	B	B	B	C	B
After upgrade: with lining on both sides of the separating wall	B	B	A	A	A	B	B
After upgrade: with lining on both sides of the separating wall and floating floor	B	B	A	A	A	B	B
After upgrade: with lining on both sides of the separating wall and suspended ceiling	B	B	A	A	A	B	A
After upgrade: with lining on both sides of the separating wall and floating floor / suspended ceiling	A	A	A	A	A	B	A

[1] See Table 6.2.1 in Annex A.
[2] See Table 6.2.2 in Annex A.
[3] ISO/TS 19488 does not provide a classification based on this index, thus the classification proposed here is based on the same values that for $D_{nT,w}$+$C_{50\text{-}3150}$ given in Table 6.2.3 in Annex A.
[4] See Table 6.2.3 in Annex A.
[5] See Table 6.2.4 in Annex A.

Table 7.4.3: Modern wood-based building – Step-by-step building improvement – Loudness evaluation in sone.

Input noise source	Pink noise	Indoor Noise NSir1 or NSir2avg	Indoor Noise NSir1 or NSir2avg + 10 dB	Indoor Noise NSir2max
Before upgrade				
Horizontal transmission	2.9231	0.4427	1.9308	1.5448
Vertical transmission – Large rooms	2.6496	0.5716	2.1031	1.6254
Vertical transmission – Small rooms	3.0760	0.7413	2.4773	1.9396
After upgrade: with lining on both sides of the separating wall				
Horizontal transmission	1.4255	0.0513	0.7786	0.5859
Vertical transmission – Large rooms	1.6966	0.2149	1.2253	0.9193
Vertical transmission – Small rooms	1.9584	0.301	1.4633	1.1087
After upgrade: with lining on both sides of the separating wall and floating floor				
Horizontal transmission	1.4201	0.0489	0.7719	0.5813
Vertical transmission – Large rooms	1.639	0.1696	1.1321	0.8478
Vertical transmission – Small rooms	1.8984	0.2556	1.3712	1.0369
After upgrade: with lining on both sides of the separating wall and suspended ceiling				
Horizontal transmission	1.2107	0.0418	0.72	0.5192
Vertical transmission – Large rooms	1.4721	0.1829	1.1279	0.8211
Vertical transmission – Small rooms	1.7548	0.2734	1.3771	1.0212
After upgrade: with lining on both sides of the separating wall and floating floor / suspended ceiling				
Horizontal transmission	1.2099	0.0399	0.7153	0.5165
Vertical transmission – Large rooms	1.4360	0.1475	1.0518	0.7634
Vertical transmission – Small rooms	1.7135	0.2363	1.3023	0.9626

Table 7.4.4: Modern wood-based building – Intermediary building improvement relative to lining on separating wall – Airborne sound insulation performance in dB.

	$D_{nT,w}$ + C	$D_{nT,w}$ + $C_{50-3150}$	$D_{nT,w}$ + C_{I40}	$D_{nT,w}$ + $C_{IndoorA}$	$D_{nT,w}$ + $C_{Indoor40}$
Before upgrade					
Horizontal transmission	53	50	56	58	59
Vertical transmission – Large rooms	54	54	56	56	56
Vertical transmission – Small rooms	53	52	54	54	55
After upgrade: with changing lining on small room side of the separating wall					
Horizontal transmission	59	55	61	63	65
Vertical transmission – Large rooms	58	57	60	61	61
Vertical transmission – Small rooms	57	56	59	59	60
After upgrade: with changing lining on large room side of the separating wall					
Horizontal transmission	57	54	60	63	64
Vertical transmission – Large rooms	58	57	60	61	61
Vertical transmission – Small rooms	57	56	59	59	60
After upgrade: with lining on both sides of the separating wall					
Horizontal transmission	61	56	62	64	65
Vertical transmission – Large rooms	58	57	60	61	61
Vertical transmission – Small rooms	57	56	59	59	60

Table 7.4.5: Modern wood-based building – Intermediary building improvement relative to lining on separating wall – Loudness evaluation in sone.

Input noise source	Pink noise	Indoor Noise NSir1 or NSir2avg	Indoor Noise NSir1 or NSir2avg + 10 dB	Indoor Noise NSir2max
Before upgrade				
Horizontal transmission	2.9231	0.4427	1.9308	1.5448
Vertical transmission – Large rooms	2.6496	0.5716	2.1031	1.6254
Vertical transmission – Small rooms	3.0760	0.7413	2.4773	1.9396
After upgrade: with changing lining on small room side of the separating wall				
Horizontal transmission	1.6327	0.0702	0.8742	0.6826
Vertical transmission – Large rooms	1.7292	0.2176	1.2389	0.9307
Vertical transmission – Small rooms	1.9584	0.301	1.4633	1.1087
After upgrade: with changing lining on large room side of the separating wall				
Horizontal transmission	1.851	0.1114	1.0314	0.7955
Vertical transmission – Large rooms	1.6966	0.2149	1.2253	0.9193
Vertical transmission – Small rooms	2.0226	0.3056	1.4864	1.1297
After upgrade: with lining on both sides of the separating wall				
Horizontal transmission	1.4255	0.0513	0.7786	0.5859
Vertical transmission – Large rooms	1.6966	0.2149	1.2253	0.9193
Vertical transmission – Small rooms	1.9584	0.301	1.4633	1.1087

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