Bergen, Norway

BNAM 2010

May 10-12

Calculation method and database for insulation against external noise

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SINTEF Building and Infrastructure has since 2008 worked on a large R&D project for a group consisting of the Climate and Pollution Agency, KLIF (the earlier Norwegian pollution control authority /Statens forurensningstilsyn, SFT), the Norwegian public roads administration (Vegdirektoratet), the Norwegian national rail administration (Jernbaneverket), the Civil Aviation Administration (Avinor)/ Oslo Airport (OSL) and the Norwegian Defence States Agency (Forsvarsbygg).

The project is dealing with further development and quality assurance of the database connected to the calculation method in SINTEF Building and Infrastructure Handbook 47 "Insulation against external noise – Calculation method and database". This is all a part of a process for transition of the Handbook 47 into an electronic, internet version where we at the same time update and qualify all the input data for the exposed parts of the building. This will be electronically published through SINTEF Building Knowledge System (BKS) / SINTEF Building Research Design Guides, the series which is the most used planning and design tool amongst Norwegian architects and engineers. In parallel we cooperate with SINTEF Information and Communication Technology (ICT) where construction data from our database shall be accessible for their additional calculation program "Støybygg". This program makes it possible when using prediction tools for estimating external noise levels from road traffic, railroad traffic, airports and industry plants, also to calculate indoor noise levels as an additional program module.

The database in Handbook 47 (mainly from 1999) consists of data for outer walls, windows, ventilation outlets and roofs. The calculation method was originally developed in 1988 by SINTEF Building and Infrastructure and is accordance with NS-EN 12354-3 (2000) Building acoustics - Estimation of acoustic performance of buildings from the performance of elements - Part 3: Airborne sound insulation against outdoor sound.

We are now in a middle of a process where we are performing a number of new laboratory tests in order to secure that the data in the database are of a good quality. At the same time we are completing the database with data for constructions that are not sufficiently incorporated to day. The selection of need for new data has been done in cooperation with the acoustic consultants in Norway. One of the reasons for focusing on an "official" database with qualified data is that the authorities being responsible for financing rehabilitation of buildings exposed to high noise levels, wants to secure that all are evaluated in an equal manner.

In this paper we will give an overview of the calculation method including reference to noise spectra for road traffic, railroad traffic and aircraft traffic. We will also focus on some interesting results from the latest laboratory measurements of windows and of ventilation outlets. Later we hope to get financial support for the measurements of outer walls and roofs.

1 Introduction

Handbook 47 [1] by SINTEF Building and Infrastructure (published in 1999, only in Norwegian) contains a simplified calculation method for insulation against external noise together with data for sound insulation of different building elements (external wall, windows, ventilation inlets and roof-constructions). The purpose is to calculate either expected indoor noise level in a known situation, or to calculate the needed performance of the elements involved when the indoor noise level is limited. The handbook is a rewritten version of two earlier publications (Guideline 19 from 1979 and Handbook 39 from1983).

All the calculations and construction data in this handbook are based upon use of a single number value (R_w + C_{tr}) for characterizing sound insulation against road traffic noise according to EN ISO 140-3 [2], EN 140-10 [3] and EN-ISO 717-1 [4]. However the method is also valid for both road traffic noise, railroad traffic noise and aircraft noise. This is possible by introducing 18 (six typically spectra for each three main type of sound source) alternatively spectrum adaptation terms (C-values) that are pre-calculated for each construction type in the database. Behind all the single number values, the full 1/3 octave band results are in use, but they are hidden to make the method practical in use.

We are now in a process where we will offer this calculation method and construction database electronically and in an internet version. This will be published through SINTEF Building Knowledge System (BKS) / SINTEF Building Research Design Guides, the series which is the most used planning and design tool amongst Norwegian architects and engineers. Then it will no longer be necessary to use the spectrum corrections manually for the constructions, and it will be also possible to have free choice of outdoor noise spectrum.

At the same time we are updating and qualifying all the input data for the exposed parts of the building. We are performing a number of new laboratory tests in order to secure that the data in the database are of a good quality. At the same time we are completing the database with data for constructions that are not sufficiently incorporated to day. The selection of need for new data has been done in cooperation with the acoustic consultants in Norway.

One of the reasons for focusing on an "official" database with qualified data is that the authorities being responsible for financing rehabilitation of buildings exposed to high noise levels, wants to secure that all are evaluated in an equal manner. This part is mainly financed by a group consisting of the Climate and Pollution Agency, KLIF (the earlier Norwegian pollution control authority /Statens forurensningstilsyn, SFT), the Norwegian public roads administration (Vegdirektoratet), the Norwegian national rail administration (Jernbaneverket), the Civil Aviation Administration (Avinor)/ Oslo Airport (OSL) and the Norwegian Defence States Agency (Forsvarsbygg).

The building regulations in Norway (new buildings) according to TEK/Norwegian Standard 8175, class C requires a maximum limit of indoor noise levels from outdoor sound sources in dwellings (living room/bedroom): $L_{pA,eq,24h} \leq 30$ dB and $L_{pA,max}$ (night, 23-07) ≤ 45 dB.

Regulations relating to pollution control states that the there is the owner of the installations (roads, railroads, airports etc.) who is responsible both for surveying and steps for actions. The surveying limit is $L_{p,Aeq,24h} = 35$ dB. The limit for actions (improvements of existing buildings) is $L_{p,Aeq,24h} = 42$ dB. By calculation of the indoor noise level it is assumed closed windows and ventilation outlets.

Those two regulations (new buildings and existing buildings) is the most important reason for the need for a common calculation model and common construction database to secure that all cases are treated equally. Especially, for existing buildings it has been an increased demand for data for old constructions with different degrees of maintenance. Different input data can lead to large differences in rehabilitation actions and in costs. It has therefore been a large focus on a better basis for sound properties of old and bad maintained constructions of the building envelope.

The construction database (which is a part of Handbook 47) consists of about 100 different external walls (lightweight and heavyweight), 150 different types of glazing and windows, 20 different types of ventilation outlets and 60 different roof constructions (lightweight and heavyweight).

This database will now be extended and renewed in connection with the ongoing project.

2 Overview of the calculation model

The calculation method is in accordance with EN 12354-3 [5]. The airborne sound insulation of a building element (apparent sound reduction index $R'_{tr,s}$) when the sound source is traffic noise can be evaluated from (1)

$R'_{tr,s} = L_{eq,1,s} - L_{eq,2} + 10 \lg (S/A) -3$ dB (1)

$L_{eq,1,s}$ is the average equivalent sound pressure level on the outside surface including reflecting effects from the façade (dB)

$L_{eq,2}$ is the average equivalent sound pressure level in the receiving room (dB)

S is the area of the building element (m^2)

A is the equivalent sound absorption area in the receiving room (m^2)

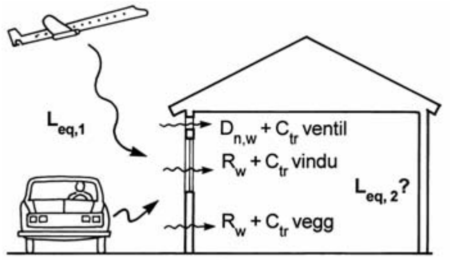

Figure 1. Illustration of the calculation model for indoor noise level. Based on outdoor noise level and the sound reduction index for external wall, window and ventilation outlets together including spectrum adaptation terms.

We have in our simplified method assumed that the apparent sound reduction index $R'_{tr,s}$ with reasonable accuracy is equal to the sound reduction index R from laboratory measurements. This implies that we have passing sound sources (traffic noise) giving different angles of incident towards the façade. In addition we recommend use of a safety margin to compensate for losses due to leakages etc in the field situation.

$R'_{tr,s} \approx R$ (lab) (2)

We use single number values in our method including spectrum adaptation terms (3). As a basis we use the standardized traffic noise spectrum (mixed road traffic, 50 km/t) 100-3150 Hz as described in EN-ISO 717-1 [4].

$R'_{tr,s} = R_w + C_{tr}$ (3)

For other types of sound sources we use other C-corrections, still calculated according to EN ISO 717-1, but with other types of sound spectra. The method offers totally 18 different pre-calculated spectra that should cover the most common situations in practice.

The method opens for calculation with several elements (parts) each described with its value for $R_w + C_{tr}$. However ventilation outlets are handled according to ISO 140-10 [3] given by the unit $D_{n,e,w} + C_{tr}$.

The resulting sound reduction for several parts with different sound reduction is calculated traditionally according to (4)

$R_{res} = 10\lg\{[S_1 + S_2 + ... + S_n] / [S_1 \times 10^{-R1/10} + S_2 \times 10^{-R2/10} + ... + S_n \times 10^{-Rn/10}]\}$ (4)

S_1 = area of part-area 1 etc.

R_1 = sound reduction index of part-area 1 etc.

In our simplified method we have from practical reasons restricted the number of exposed facades (wall and roof) to three where each of those three can consist of three part-areas (for instance external wall, window and ventilation outlet).

The sound reduction index for different elements can be found directly from the construction database in the handbook or from product data directly from producers etc.

The simplified method can calculate two different main situations:

- Calculation of indoor noise level based on known construction (external wall, window, ventilation outlets and roof) for the exposed facades.
- Calculation of needed sound reduction of the different parts of the façade (external wall, window, ventilation outlets and roof) to obtain a specific indoor noise level.

For the last option we can vary the mutual ”strength” between the part-areas. This opens e.g. for choosing between a moderate window and a good wall or vice versa depending of what is best suitable in the situation.

3 Some results of laboratory measurements of windows

Concerning the windows, one main target in this project has been to establish data for typically windows with different degree of air leakages. This is especially important when one shall estimate the indoor noise levels for existing building and further evaluate the need for renovation.

We will here give some results from the measuring program in 2009. One of the questions we focused on was this: *How bad will windows in existing buildings perform acoustically when the quality is low (bad maintained, bad air tightness, large leakages etc.)?*

To answer this question we set up a test program using three different types of windows (outward opening window, inward opening window and coupled window). For these windows we varied the degree of tightening from good to extremely bad. For practical reasons we could not provide old windows to these tests. Instead we had made for us new test windows with ordinary profiles (casement/frame and jamb/sill) included systems for hinging, weather stripping and closing/opening). We then manipulated the tightening during the tests as shown in table 1.

Figure 2 – 4 shows the three different types of windows (outward opening, inward opening and coupled window)

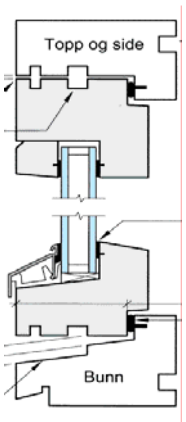

Figure 2. Outward opening window

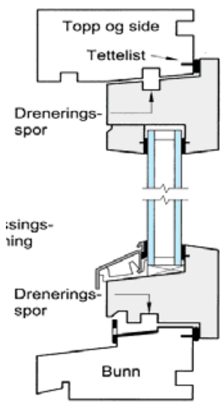

Figure 3. Inward opening window

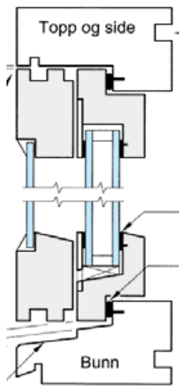

Figure 4. Coupled window (two superimposed casements)

Table 1. Classification the degree of tightness

Classification of tightening	**Description of tightening**
Good	Standard performance from producer (primary weather strip + possible additional weather strip
Ideal	Standard performance from producer + artificial supplementary tightening in laboratory
Limited	5 x 10 mm openings in the weather strip on the top and bottom of the window
Fair	Weather strip exchanged with wood moulding filling the whole slit (wood to wood)
Bad	3 x 10 mm wood moulding at all four sides in 4 mm clearance between casement/frame and jamb/sill. Means that there is about 1 mm clearance (1 mm open slit)
Extremely bad	Without weather strip. Means that there is about 4 mm clearance between casement/frame and jamb/sill. (4 mm open slit)

Foto1 shows window mounted in the test laboratory. Diagram 1 shows the test results of the sound reduction index in 1/3 octave bands for the coupled window (4-40,5-4) from good to extreme bad tightening. Diagram 2 shows the test results of the sound reduction index in 1/3 octave bands for the inward opening window (4-12-4-12-4) from good to extreme bad tightening.

Foto 1. Window mounted in the test laboratory.

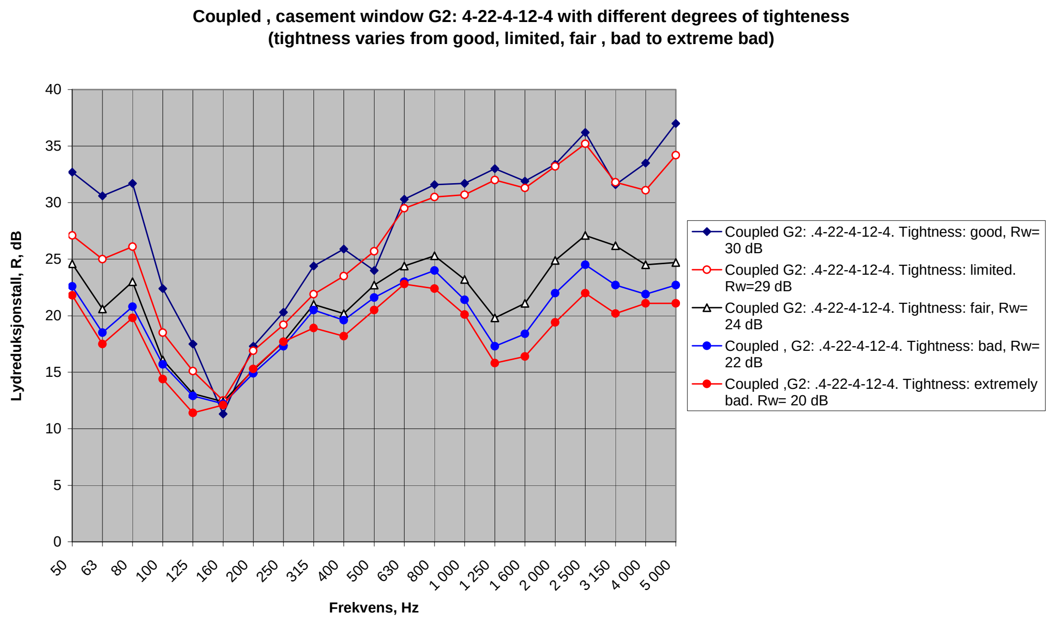

Diagram 1. Sound reduction index in 1/3 octave bands for the coupled window (4-40,5-4) from good to extreme bad tightening

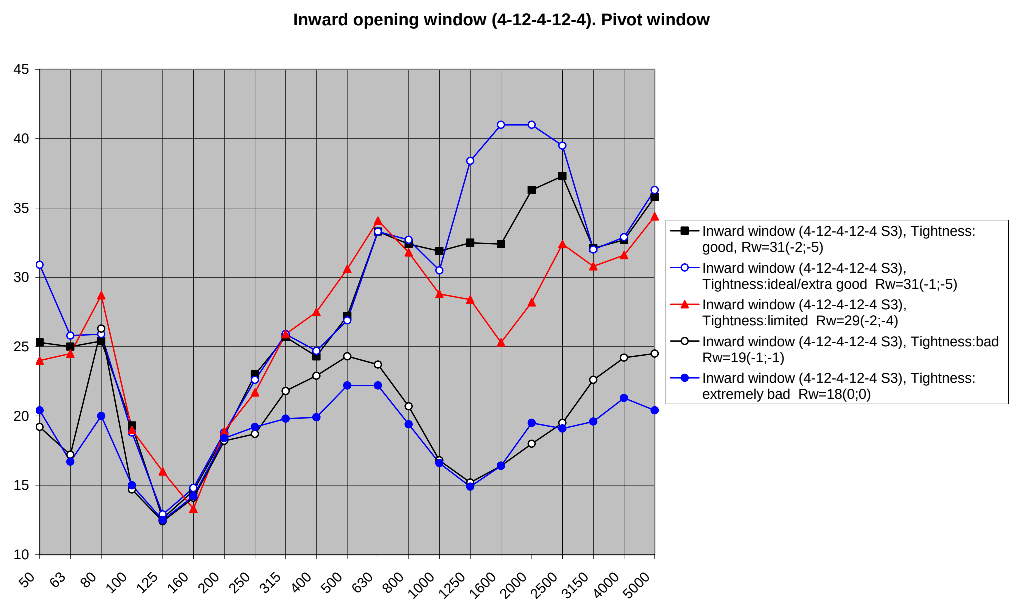

Diagram 2. Sound reduction index in 1/3 octave bands for the inward opening window (4-12-4-12-4) from good to extreme bad tightening.

Table 2 gives an overview of the single number values from the test of the three different windows types with tightening varying from good, limited, bad and extremely bad.

Table 2. Overview of the single number values from the test of the three different windows types with tightening varying from good, limited. bad and extreme bad.

Window type	Glass combination	Good tightness			Limited tightness			Bad tightness			Extreme bad tightness		
		R_w	C_{tr}*	**R_w+ C_{tr}***	R_w	C_{tr}*	**R_w+ C_{tr}***	R_w	C_{tr}*	**R_w+ C_{tr}***	R_w	C_{tr}*	**R_w+ C_{tr}***
Coupled window	4-40-4	27	-4	**23**	22	-2	**20**	20	-2	**18**	19	-2	**17**
	4-22-(4-12-4)	30	-5	**25**	24	-3	**21**	22	-2	**20**	20	-2	**18**
Inward opening window	(4-12-4-12-4)	31	-5	**26**	29	-4	**25**	19	-1	**18**	18	0	**18**
	(8-20-4/1/4)	40	-4	**36**	34	-2	**32**	23	0	**23**	23	0	**23**
Outward opening window	(4-15-4)	32	-5	**27**	31	-4	**27**	24	-2	**22**	19	-1	**18**
	(4-10-4/1/4)	39	-5	**34**	34	-3	**31**	24	-1	**23**	19	-1	**18**
In-/ out **	4-120-4	34	-4	**30**				27	-2	**25**			

* C_{tr}= 100-3150 Hz

**Results from SINTEF Building Research Design Guides no. 733.109

4 Some results of laboratory measurements of ventilation outlets

Concerning the ventilating outlets we have found errors in some product data for sound reduction of common used products, overestimating the high-frequency damping due to wrong mounting in the test laboratories. We have during the last years also completed the data for ordinary, un-dampened ventilation outlets for the same reason as mentioned above for the windows. At the same time we have focused on data both for closed and open ventilation outlets because the procedure for estimating indoor noise level of existing building according to the requirements by the authorities assumes closed ventilation outlets.

In our test program winter 2009-2010 we have measured seven main types, all in both open and closed position. The standard test procedure is given in NS-ISO 140-10 [3] and the performance shall be given by the unit "element-normalized level difference, $D_{n,e}$" or "weighted, element-normalized level difference, $D_{n,e,w}$"

Table 3 gives an overview of the seven different types of ventilation outlets that has been tested.

Table 3. Overview of the seven different types of ventilation outlets that has been tested. Totally 76 tests.

Ventilation type	Main description
1	Un-dampened round ventilation outlet Ø 80 mm for mounting in external walls with thickness of 200, 300 og 400 mm. Totally 24 different tests
2	Dampened round ventilation outlet Ø 80 mm for mounting in external walls with thickness of 200, 300 og 400 mm. Totally 18 different tests
3	Dampened round ventilation outlet Ø 100 mm for mounting in external walls with thickness of 200, 300 og 400 mm. Totally 12 different tests
4	Dampened ventilation outlet for mounting in a slit of the head jamb of a window Totally 6 different tests
5	Dampened ventilation outlet made of perforated steel plate mounted inside a 200 mm thick light weight outerwall timber filled with 200 mm mineral wool. Totally 2 different tests
6	Dampened ventilation outlet for radiator mounted inside the wall and with round pipe through a 200 mm external wall. Totally 4 different tests
7	Dampened, mechanical ventilation unit outlet mounted inside the wall with round pipe through a 200 mm external wall (with and without heat exchanger). Totally 10 different tests

Table 4 gives an overview of the single number values from the test of the dampened, round ventilation outlet Ø 80 mm with mounted in walls with thickness of 200 mm, 300 mm and 400 mm. Ref. ISO 140-10 [3] and EN-ISO 717-1 [4].

Table 4. Overview of the single number values from the test of the dampened, round ventilation outlet Ø 80 mm.

Ventilation type and length	$D_{n,e,w}$, dB		$C_{tr,50-5000}$, dB	
	Open	Closed	Open	Closed
Fresh 80dB, L=200 mm inner part, type A	43	47	-2	-2
Fresh 80dB, L=200 mm inner part, type B	42	46	-1	-2
Fresh 80dB, L=200 mm inner part, type C	43	53	-2	-3

Table 5 gives an overview of the single number values from earlier tests of ordinary, un-dampened ventilation outlets (150 mm x 150 mm flap-hatch and un-dampened ventilation outlet for mounting in a slit of the head jamb of a window)

Table 5. Overview of the single number values from earlier tests of ordinary, un-dampened ventilation outlets

Ventilation type	$D_{n,e,w}$, dB		$C_{tr,50-5000}$, dB	
	Open	Closed	Open	Closed
Un-dampened 150 mm x 150 mm flap-hatch of steel plates mounted in a 270 mm thick wall	28*	45	0	-3
un-dampened ventilation outlet for mounting over a slit of the head jamb of a window - Area 15 x 220 mm, depth 45 mm - Area 15 x 420 mm, depth 45 mm - Area 15 x 620 mm, depth 45 mm	 32 29 28	 43	 0 0 0	 -2

*max opened

Diagram 3 shows the test results of the sound reduction index in 1/3 octave bands for the un-dampened, round ventilation outlet Ø 80 mm (open and closed) mounted in walls with thickness of 200 mm, 300 mm and 400 mm.

Diagram 4 shows the test results of the sound reduction index in 1/3 octave bands for the dampened, mechanical ventilation unit outlet mounted inside the wall with round pipe through a 200 mm external wall (with and without heat exchanger)

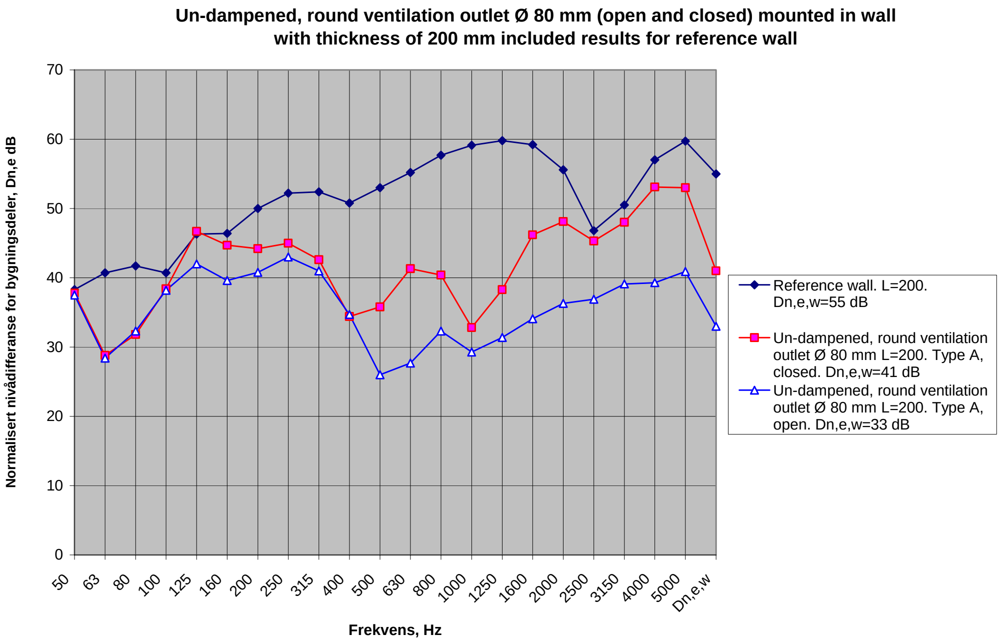

Diagram 3. Test results of the sound reduction index in 1/3 octave bands for the un-dampened, round ventilation outlet Ø 80 mm (open and closed) mounted in walls with thickness of 200 mm, 300 mm and 400 mm

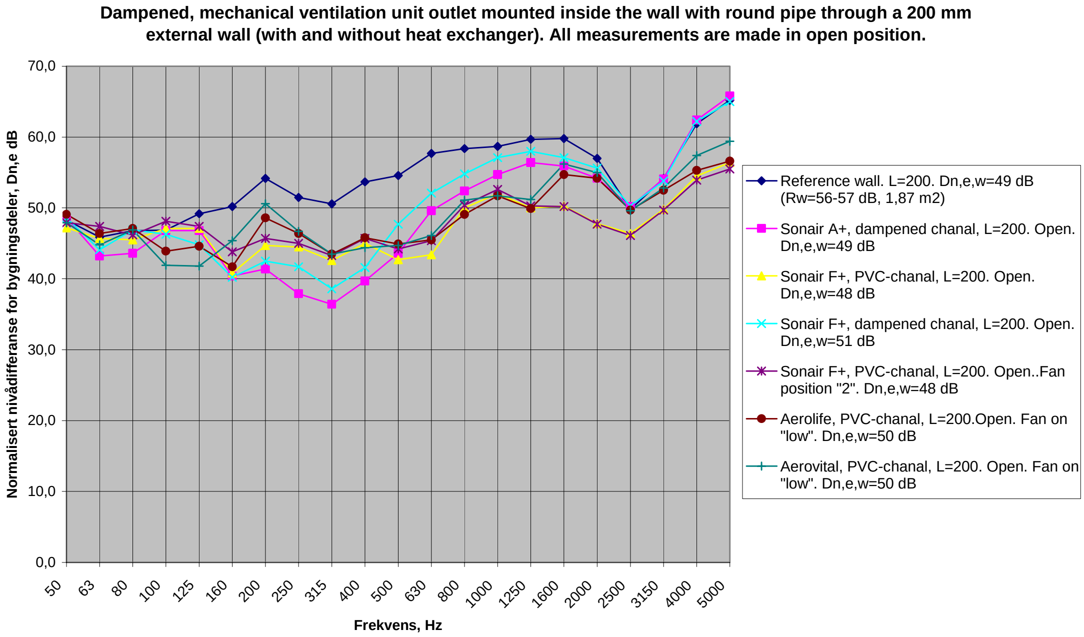

Diagram 4. Test results of the sound reduction index in 1/3 octave bands for the dampened, mechanical ventilation unit outlet mounted inside the wall with round pipe through a 200 mm external wall (with and without heat exchanger). All measurements are made in open position.

References

[1] Homb, Anders og Hveem, Sigurd. Isolering mot utendørs støy. Norges byggforskningsinstitutt, Håndbok 47. Oslo, 1999

[2] ISO 140-3. Acoustics - Measurement of sound insulation in buildings and of building elements - Part 3: Laboratory measurements of airborne sound insulation in building elements

[3] ISO 140-10. Acoustics - Measurement of sound insulation in buildings and of building elements - Part 10: Laboratory measurement of airborne sound insulation of small building elements - (= EN 20140-10:1992)

[4] EN ISO 717-1. Acoustics - Rating of sound insulation in buildings and of building elements - Part 1: Airborne sound insulation

[5] EN 12354-3. Building acoustics - Estimation of acoustic performance of buildings from the performance of elements - Part 3: Airborne sound insulation against outdoor sound