

# National and European requirements concerning acoustic insulation from air sounds for internal walls

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**Abstract.** Neighbourhood noises in newly erected residential buildings are problems which are more and more frequently raised by their inhabitants. Pursuant to the binding European norms, the way of testing acoustic insulation properties has been standardized, however both required values and indices used to express them remain at the discretion of individual countries of the European Community. In the article, single-number acoustic insulation indices for air sounds used in Europe are presented and the methods of converting them are described. Current national requirements concerning acoustic insulation properties for interior walls within the apartment and between apartments in multi-family buildings as well as their comparison with requirements applicable in selected countries of the Western, Central and Southern Europe are presented. Based on the provided data, the evaluation of national requirements regarding acoustic insulation properties for interior walls was carried out. It was concluded that Polish acoustic requirements for interior walls are at a low level not only compared to the countries of the Western Europe, but also Central and Southern Europe.

## 1. Introduction

Noise is one of the most essential factors negatively affecting health and quality of life of the contemporary man. Both European [1] and national [2, 3] regulations mention protection from noise as one of seven fundamental mandatory requirements which should be fulfilled by building structures. The European regulations do not specify the level of the requirements but their scope, parameters used to formulate them, principles of checking them, whether the basic requirement is fulfilled as well as technical specifications and guidelines for European technical approvals. Buildings should be protected from the following noise [4]:

- external air noise;
- air noise penetrating between interior spaces;
- impact noise;
- noise generated by technical equipment;
- noise caused by excessive reverberation.

Requirements regarding acoustic insulation properties in the residential building industry exist in more than 30 European countries. In some of them, they have been binding since the nineteen fifties [5], in Poland the first standard concerning soundproof protection of buildings was published in 1954 [6].

Current methods regarding testing of acoustic insulation properties are included in the European standards. However, even though the methods of measuring acoustic insulation properties have been standardized within the European Community, requirements concerning single number indices and their minimal values are the responsibility of individual member states. The international standard valid in Poland and other European countries ISO 717-1 allows application of various single number



indices for acoustic insulation properties and spectral adaptive indices for various frequency ranges [7].

## 2. Single number acoustic insulation indices for air sounds

Requirements concerning acoustic insulation from air sounds refer to standard single number indices. The regulations binding within this scope in Poland are expressed as minimum single number acoustic insulation indices [8]. Requirements for interior partitions within the apartment are specified using the  $R_{A1R}$  index. In order to evaluate the acoustic insulation properties of partitions between apartments, the  $R'_{A1}$  and  $D_{nT,A1}$  indices are used.

Apparent evaluation rate of sound reduction  $R'_{A1}$  (taking into account flanking transmission of sound) is described using the formula (1):

$$R'_{A1} = R'_w + C \text{ [dB]}. \quad (1)$$

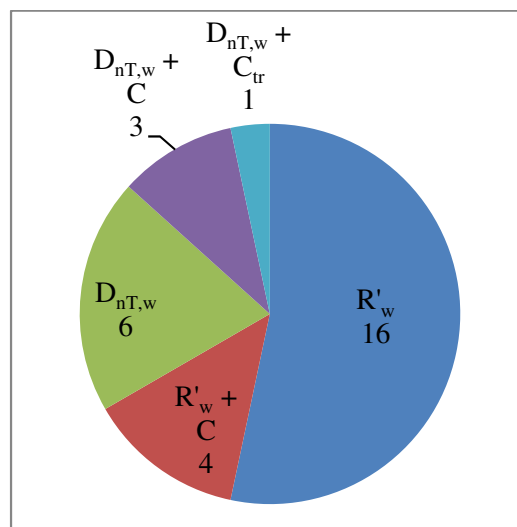
In the presented formula,  $R'_w$  is a weighted apparent sound reduction index determined by comparing the reference calibration curve to the characteristics of approximate specific acoustic insulation properties  $R'$  within the considered frequency range.  $C$  is A-weighted pink noise spectrum adaptation term which takes into account the spectrum of sounds having an effect on the partition, characteristic for noise occurring inside residential buildings. This index can have negative values or values equal to zero.

The index indicating the evaluation of reference difference of levels  $D_{nT,A1}$  is used when neighbouring spaces are shifted versus each other in such a way that the common part of the partition constitutes only a fragment of the considered wall or if the surface area of the common part of the partition is lower than 10 m<sup>2</sup>. It is determined using the formula (2):

$$D_{nT,A1} = D_{nT,w} + C \text{ [dB]}, \quad (2)$$

where  $D_{nT,w}$  is a weighted index of the reference difference of levels obtained by comparing the reference curve to the characteristics of the reference difference of acoustic pressure levels  $D_{nT}$  within the considered frequency range. The reference difference of acoustic pressure levels is acoustic insulation between spaces converted to the reference conditions determined by reverberation time  $T_0 = 0.5$  s (specific for furnished spaces).

In European Union countries, various parameters regarding acoustic insulation from air sounds are used. Figure 1 presents types of indices according to EN ISO 717-1 and the number of European countries in which they are used to formulate requirements concerning acoustic insulation from air sounds [9].



**Figure 1.** Breakdown regarding the use of single number indices of acoustic insulation from air sounds for 30 selected European countries

Not only single number indices of acoustic insulation but also requirements concerning their minimum values show considerable differentiation between individual European countries.

### 3. Proposals for standardizing European indices of acoustic insulation from air sounds

As a part of work aimed at integration and harmonization of regulations regarding acoustic insulation in Europe, it was proposed to standardize the indices and requirements concerning acoustic insulation from air sounds. According to literature available in this field [10], the index for evaluation of the reference difference of levels described by the following formula is regarded as the preferred one (3):

$$D_{nT,50} = D_{nT,w} + C_{50-3150} \text{ [dB]}. \quad (3)$$

The advantage of accepting the reference difference of acoustic pressure levels  $D_{nT}$  as the basic measurement parameter is, among other things, the considerable availability of data and experience in using it in many European countries, and the lack of any necessity to measure the volume of spaces and surface area of tested elements.

The lower threshold of measurement frequencies extended versus the existing one in 1/3 octave bands up to 50 Hz (currently it is equal to 100 Hz) was accepted as essential mainly for the acoustic characteristics of light building structures. The upper threshold of measurement frequencies in 1/3 octave bands equal to 3150 Hz was regarded as sufficient for the characteristics of acoustic properties of building partitions [10].

### 4. Dependence between indices used in Europe and requirements concerning acoustic insulation from air sounds

According to [11], in order to convert the specific acoustic insulating properties  $R'$  to the reference difference of acoustic pressure  $D_{nT}$ , the dependence described by the formula (4) can be used:

$$D_{nT} = R' + 10 \lg V \cdot \frac{0.16}{T_0 \cdot S} \quad (4)$$

where:  $V$  is the volume of the receiving space [ $\text{m}^3$ ],  $T_0$  is the reverberation time [s], and  $S$  is the surface area of the partition between the transmitting and receiving space [ $\text{m}^2$ ].

In the case of conversion between weighted indices of acoustic insulation from air sounds, their differentiated frequency ranges and calculation procedures should be taken into account. The measurement frequency range commonly used so far for 1/3 octave bands is 100 – 3100 Hz.

Direct comparison of requirements and single number indices used in various countries of the European Union is very difficult. This results from the fact that there are no simple mathematical dependencies between them. Such estimation can be made only based on existing experience and obtained statistical dependencies. Results of these types of dependencies vary for different types of partitions, for example light framing structures and massive brick walls. The attempt to convert values of various single number sound reduction indices to  $D_{nT,50}$  values was undertaken by Dunbavin and Gerretsen [11] using the formulas (5-8):

$$R'_w: D_{nT,50} = R'_w - 1.0 + (5.2 - 0.12 \cdot R'_w), \quad (5)$$

$$D_{nT,w}: D_{nT,50} = D_{nT,w} + 5.2 - 0.12(D_{nT,w} + 1.0), \quad (6)$$

$$D_{nT,A1}: D_{nT,50} = D_{nT,A1} + 6.2 - 0.12(D_{nT,A1} + 2.0), \quad (7)$$

$$D_{nT,A2}: D_{nT,50} = D_{nT,A2} + 10.2 - 0.12(D_{nT,A2} + 6.0). \quad (8)$$

The presented dependencies were used to compare the requirements of acoustic insulation for walls inside residential buildings in Poland and in selected European countries. The calculation results are shown in table 1.

It can be concluded from the presented data that Polish requirements concerning acoustic insulation from air sounds for internal walls are relatively low. This concerns especially vertical partitions between apartments. Among countries for which requirements were quoted in table 1, lower values

were found only in the case of the Romanian standard (calculated value of index  $D_{nT,50} \geq 49$  dB) and lowest category of dwellings in Belarus standard (calculated value of index  $D_{nT,50} \geq 48$  dB). Higher requirements were recorded in all other analysed countries.

**Table 1.** Requirements concerning acoustic insulation of walls inside residential buildings in Poland and in selected European countries.

Country		Required acoustic insulation [dB]			
		Walls between rooms in dwelling		Walls between dwellings	
		Sound Reduction Index	$D_{nT,50}$	Sound Reduction Index	$D_{nT,50}$
<b>POLAND</b> [8]		$R_{AI,R} \geq 35-38$	32-37	$R'_{AI} \geq 50$	50
<b>LITHUANIA</b> – (in dependence on the category of building) [12]	category A	$R'_w \geq 40$	39	$R'_w \geq 63$	60
	category B	$R'_w \geq 35$	35	$R'_w \geq 58$	55
	category C*	$R'_w \geq 30$	31	$R'_w \geq 55$	53
	category D	$R'_w \geq 25$	26	$R'_w \geq 52$	50
	category E	$R'_w \geq 20$	22	$R'_w \geq 48$	46
<b>LATVIA</b> [13]		$R'_w \geq 45$	44	$R'_w \geq 54$	52
<b>ESTONIA</b> [14]		$R'_w \geq 43$	42	$R'_w \geq 55$	53
<b>BELARUS</b> [15]	category A	$R'_w \geq 45$	44	$R'_w \geq 54$	52
	category B	$R'_w \geq 43$	42	$R'_w \geq 52$	50
	category W	$R'_w \geq 43$	42	$R'_w \geq 50$	48
<b>CZECH REPUBLIC, SLOVAKIA</b> [16, 17]		$R'_w \geq 42$	41	$R'_w \geq 53$	51
<b>HUNGARY</b> [18]		$R'_{AI} \geq 37$	39	$R'_{AI} \geq 51$	51
<b>ROMANIA</b> [19]		$\Gamma_a \geq 32$	32	$\Gamma_a \geq 51$	49
<b>GERMANY</b> [20]		-	-	$R'_w \geq 53$	51

\* Lowest acoustic class for the new buildings

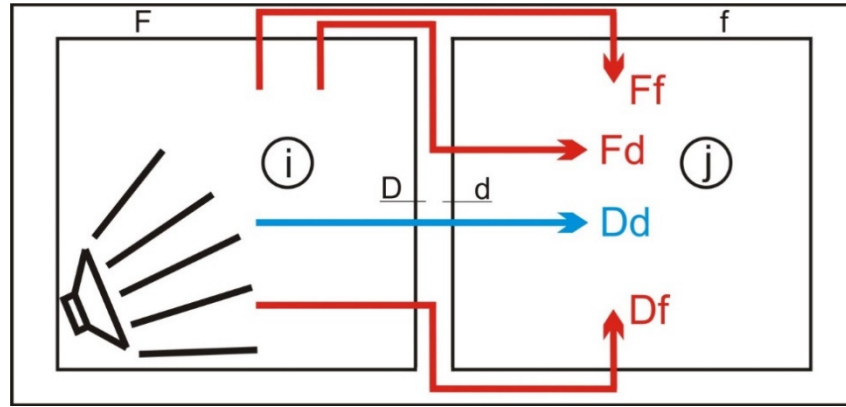
Tests regarding evaluation of insulation acoustic properties for walls in residential apartments conducted in Poland in the seventies and the eighties of the previous century showed dissatisfaction in approximately 20 % of their inhabitants which also indicates the need to increase requirements regarding acoustic insulation of internal walls in residential buildings [4, 21-23]. Furthermore, it should be taken into consideration that walls erected in the seventies of the previous century were characterized by higher density and surface mass compared to many currently common light brick structures. Tests carried out in other countries of the European Community, often with higher acoustic requirements, also indicate that inhabitants of multi-apartment buildings experience the negative effects of noise caused by co-inhabitants. Based on the conducted surveys and statistical research, it is estimated that more than 50 million Europeans are exposed to neighbourhood noise which negatively affects their quality of life [5].

In spite of relatively low national requirements concerning the acoustic insulation properties of partitions between apartments, it should be stated that their fulfilment is not an obvious thing and requires use of materials having high acoustic parameters both with respect to horizontal and vertical partitions and appropriate selection of the method of bonding. In design calculations regarding acoustic insulation of walls between apartments, it should be borne in mind that it is impossible to derive a direct dependence between values of acoustic insulation obtained in laboratory tests and their values in actual structures.

## 5. Calculation of acoustic insulation using the simplified method

In order to obtain an appropriate forecast regarding acoustic insulation of walls between apartments from air sounds, the effect of transmitting sound via the direct route (through the calculated partition)

and all side routes should be determined. The effect of flanking transmission of sound on acoustic insulation properties of partitions in the building is determined using the resultant of acoustic insulation for flanking transmission of sound via material routes. The scheme of air sound transmission routes is illustrated in figure 2.



**Figure 2.** Scheme of air sound transmission routes between spaces [22, 24].

According to the Sound Reduction Indices that are valid in Poland, the calculations regarding acoustic insulation from air sounds using the simplified method given in EN 12354-1 [24] are based on apparent sound reduction indices  $R_{A1}$  [dB]. For the calculations, an equation given in formula (9) is used,

$$R'_{A1} = -10 \lg \left[ 10^{-0,1R_{Dd,A1}} + \sum_{F=f=1}^n 10^{-0,1R_{Ff,A1}} + \sum_{f=1}^n 10^{-0,1R_{Df,A1}} + \sum_{F=1}^n 10^{-0,1R_{Fd,A1}} \right] \text{ [dB]}, \quad (9)$$

where:

$R'_{A1}$  - apparent evaluation rate of sound reduction [dB] described in equation (1);

$R_{Dd,A1}$  - specific acoustic insulation properties of the direct route (through the partition separating spaces) [dB];

$R_{Ff,A1}$ ,  $R_{Df,A1}$ ,  $R_{Fd,A1}$  - acoustic insulation properties of side routes [dB] according to markings in fig. 2;

$n$  - number of side partitions in the room; usually  $n = 4$ .

Flanking apparent sound reduction index ( $R_{ij,A1}$ ) for the paths of sound given in figure 2 are described by the formulas (10-12). They depend on the sound transmission routes and on material and structural data of building partitions:

$$R_{Ff,A1} = \frac{R_{F,A1} + R_{f,A1}}{2} + \Delta R_{Ff,A1} + K_{Ff} + 10 \log \frac{S_s}{l_0 l_f} \text{ [dB]}, \quad (10)$$

$$R_{Fd,A1} = \frac{R_{F,A1} + R_{s,A1}}{2} + \Delta R_{Fd,A1} + K_{Fd} + 10 \log \frac{S_s}{l_0 l_f} \text{ [dB]}, \quad (11)$$

$$R_{Df,A1} = \frac{R_{s,A1} + R_{f,A1}}{2} + \Delta R_{Df,A1} + K_{Df} + 10 \log \frac{S_s}{l_0 l_f} \text{ [dB]}. \quad (12)$$

$R_{F,A1}$  is an apparent sound reduction index for element  $F$  in the transmitting space [dB],

$R_{f,A1}$  is an apparent sound reduction index for element  $f$  in the transmitting space [dB],

$\Delta R_{Ff,A1}$  is a total apparent sound reduction index of the growth of specific acoustic insulation of the system on the side element on the transmitting and/or receiving side [dB],

$\Delta R_{Fd,A1}$  is a total apparent sound reduction index of the growth of specific acoustic insulation of the system on the side element on the transmitting and/or of separating element on the receiving side [dB],

$\Delta R_{Df,A1}$  is a total apparent sound reduction index of the growth of specific acoustic insulation of the system on the separating element on the transmitting side and/or on the side element on the receiving side [dB],

$K_{Ff}$  is a vibration reduction index of the wall junction on sound path  $Ff$  [dB],

$K_{Fd}$  is a vibration reduction index of the wall junction on sound path  $Fd$  [dB],

$K_{Df}$  is a vibration reduction index of the wall junction on sound path  $Df$  [dB],

$S_s$  is an area of separating element [m<sup>2</sup>],

$l_f$  is a length of the junction of separating element with side elements  $F$  and  $f$  [m],

$l_0$  is a reference length,  $l_0 = 1\text{m}$ .

It should be taken into consideration that according to the Polish demands, apparent sound reduction indices of materials ( $R_{A1}$ ) should be decreased by 2 dB to so called design values of apparent sound reduction indices ( $R_{AIR}$ ).

As an example of determining airborne acoustic insulation, the calculations for the aerated concrete wall between apartments, density 700 kg/m<sup>3</sup> and thickness 400 mm, plastered on both sides using lime-cement mortar 2 x 10 mm thick, dimensions 4.61 x 2.70 m are presented. Autoclaved aerated concrete in density class 700 kg/m<sup>3</sup> and thickness 400 mm is not currently produced in Poland. The material was chosen in this way to examine the possibility of fulfilling acoustic requirements for this type of wall, using its relatively high surface mass. The design apparent sound reduction index  $R_{AIR}$  of such a partition is equal to 53.0 dB. It has been calculated as partition between full reinforced concrete ceilings, thickness 160 mm, with a floating floor made of mineral wool, thickness 30 mm, and with cement screed 40 mm, for which the design index for evaluation of acoustic insulation properties  $R_{AIR} + \Delta R_{AIR} = 54.0 + 2.0$  dB. Material data for all partitions, calculated ratios of surface masses of the calculated partition ( $m_s'$ ) for circumferential partitions ( $m_f'$ ) and vibration reduction indices for rigid cross junctions on all flanking sound transmission routes are presented in table 2.

**Table 2.** Material data for the wall between apartments and circumferential partitions together with the summary of acoustic insulation properties, surface masses and vibration reduction indices  $K_{ij}$ .

Wall/Ceiling	Material	Surface mass $m'$ [kg/m <sup>2</sup> ]	$R_{AIR}$ [dB]	$m_s'/m_f'$ [kg/kg]	$K_{Ff}$ [dB]	$K_{Fd}$ [dB]	$K_{Df}$ [dB]
Wall between dwellings	Aerated concrete, class 700 kg/m <sup>3</sup>	280	53.0	-	-	-	-
Ceiling between dwellings No 1 (F=f=1)	Reinforced concrete slab	384	54.0 +2.0	0.73	6.5	8.8	8.8
Ceiling between dwellings No 2 (F=f=2)	Reinforced concrete slab	384	54.0	0.73	6.5	8.8	8.8
Wall between rooms in dwellings (F=f=3)	Aerated concrete, class 600 kg/m <sup>3</sup>	72	38.0	3.89	20.8	10.7	10.7
External wall (F=f=4)	Aerated concrete, class 500 kg/m <sup>3</sup> + ETICS	125	40.0	2.24	11.3	6.4	6.4

On the grounds of the provided input data, calculations regarding acoustic insulation properties were carried out for all sound transmission routes according to the formulas (10-12) and resultant acoustic insulation properties were calculated for a wall between apartments made of autoclaved aerated concrete, class 700, according to the formula (9). The calculation results are shown in table 3.

On the basis of the calculations it was concluded that the autoclaved aerated wall with above-average density  $700 \text{ kg/m}^3$  and thickness 400 mm, characterized by a relatively high design index for evaluation of acoustic insulation properties  $R_{A1R} = 53.0 \text{ dB}$  ( $R_{A1} = 55.0 \text{ dB}$ ), after taking into consideration flanking transmission in analysed set of compartments achieved the value of apparent evaluation rate of sound reduction index  $R'_{A1} = 49.4 \text{ dB}$ . Correction for flanking transmission of this wall reached the value of 3.6 dB. According to the presented calculations and bearing in mind the assortment of aerated concrete that is currently being produced in Poland it can be stated that this kind of walls does not meet Polish requirements for acoustic insulation of partitions between dwellings ( $R'_{A1} \geq 50 \text{ dB}$ ).

**Table 3.** Component values of indices for evaluation of acoustic insulation properties for all sound transmission routes and calculated approximate index for evaluation of specific acoustic insulation properties for an aerated concrete wall between apartments in the layout of aerated concrete walls and reinforced concrete ceilings

COMPONENT VALUES OF INDICES FOR EVALUATION OF ACOUSTIC INSULATION							
Wall between dwellings:	[dB]	Ceiling No 1:			Wall between rooms in dwellings:		
$R_{1,d} =$	68.6	$R_{D1} =$	68.6	dB	$R_{D3} =$	62.8	dB
$R_{2,d} =$	66.6	$R_{11} =$	67.8	dB	$R_{33} =$	65.4	dB
$R_{3,d} =$	62.8	Ceiling No 2:			External wall:		
$R_{4,d} =$	59.5	$R_{D2} =$	66.6	dB	$R_{D4} =$	59.5	dB
-		$R_{22} =$	64.8	dB	$R_{44} =$	58.0	dB
APPARENT EVALUATION RATE OF SOUND REDUCTION FOR THE CALCULATED WALL BETWEEN DWELLINGS:					$R'_{A1} =$	<b>49.4</b>	<b>dB</b>

The use of walls of great thickness for the construction of partitions between dwellings is also not economically justified due to the occupancy of a larger residential area than thinner walls of high density and higher acoustic parameters.

It has to be stated that aerated concrete blocks with volume density of  $700 \text{ kg/m}^3$ , and thickness of 250 mm, that are from time to time being used as the material for walls between dwellings cannot meet Polish requirements of acoustic insulation. Apparent evaluation rate of sound reduction  $R'_{A1}$  for this type of walls in most of the cases vary from 44 to 47 dB.

## 6. Conclusions

The paper presents the comparison of requirements for acoustic insulation of walls inside residential buildings in Poland and selected European countries. Based on the calculations and comparisons made, it has been concluded that currently, in the European countries considerable differentiation appears with respect to requirements and indices used for evaluation of acoustic insulation of walls inside the buildings. In order to compare the requirements, diversified single-number indices were brought to the value of the weighted standardized level difference with spectrum adaption term  $D_{nT,50}$ . Standardization of the evaluation of acoustic properties is essential not only due to international exchange of working experience but also due to problems connected with the trade in building products between countries belonging to the European Union.

As a result of conducted comparison it has been concluded that the Polish acoustic requirements for internal walls introduced in 2015 are at a low level not only compared to the countries of Western, but also to Eastern and Southern Europe. Lower required values were recorded only in Romania and for the lowest category of apartments in Belarus. Pursuant to the UE [1] and national associated regulations [2, 3] *'the building and equipment associated with it should be designed and erected in a*

way that ensures that the level of noise to which users or people staying in its neighbourhood will be exposed does not cause any danger to their health, and also allows their work, rest and sleep in satisfactory conditions’.

The acoustic comfort survey conducted in the previous years in Poland pointed on high dissatisfaction of residents with the acoustic insulation of walls between dwellings. It should be noted that the traditional, massive walls made in the buildings under evaluation are characterized by significantly higher acoustic insulation than many of the currently used material solutions. As a negative example of such technologies, the calculations of sound insulation of 400 mm thick cellular concrete wall were presented, for which the sound reduction index of 49 dB has been obtained (Polish requirements has not been met). Although the requirements and principles of building acoustics calculations are included in relevant documents, they are often neglected and omitted in the practice of designing residential buildings. One should remember that the commonly used solutions of light partitions have a negative impact on their acoustic properties which often does not meet the required values.

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