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Published in:
22nd International Congress on Acoustics ICA 2016

Publication date:
2016

Document Version
Publisher's PDF, also known as Version of record

ICA 2016 BUENOS AIRES
Buenos Aires – 5 to 9 September 2016
Acoustics for the 21st Century…

PROCEEDINGS of the 22nd International Congress on Acoustics

Legislation and Regulations in Building Acoustics: Paper ICA2016-487

Comparison of acoustic regulations for housing and schools in selected countries in Europe and South America – A pilot study

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Abstract

Acoustic regulations for housing and schools exist in most countries in Europe, the main reasons being protection of health of citizens in their homes and optimizing learning and work conditions in schools. Comparative studies in Europe have shown a high diversity of descriptors and limit values for acoustic requirements. Considering globalization and noise as a health issue, it is important also to extend attention to other parts of the world and establish dialogue and hopefully cooperation, thus facilitating exchange of experience with construction solutions fulfilling different levels of requirements. As a pilot study, acoustic regulations in three countries in South America, namely Argentina, Brazil and Chile, have been considered. The findings indicate weaker requirements than typical in Europe, and at both continents there is a joint challenge to review regulatory requirements in those countries with a high need for improvement of acoustic conditions in housing and schools. It is concluded that one of the first steps is to create awareness among authorities and building industry and to exchange experience about construction solutions, which in many cases are quite simple. The paper includes examples of specific acoustic requirements on airborne and impact sound insulation, noise from traffic and from service equipment for housing and schools and in addition on reverberation time for class rooms and provides the basis for discussing future cooperation on optimizing acoustic regulations.

Keywords: acoustic regulations; housing; schools; sound insulation; reverberation time

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1 Introduction

In Europe most countries have acoustic regulations for housing. Such regulations require that all new residential buildings meet certain requirements for sound insulation and noise. In several countries, there are also acoustic regulations for educational buildings. If the rest of the world is considered, there are many countries with acoustic regulations for buildings but there are many more that still lack it. This pilot study intends to provide a first impression of the extent and level of acoustic regulations for housing and schools and about standards and descriptors applied, based on the present regulations in a small group of selected countries in Europe and South America.

2 Choosing countries in South America and Europe

As a starting point, based on previous studies, a number of countries in Europe were selected to represent different geographical parts, different descriptors, different level of requirements and different climates. The countries selected were Austria, Belgium, Czech Republic, Denmark and Spain. Aiming at increasing the size and interest of this study, and also due to the historical and cultural relations of South American countries to Southern Europe countries, this region was chosen as part of this comparative pilot study. Besides, the situation in South America is quite unknown which increased the interest of this study.

The three sample countries in South America (Argentina, Brazil and Chile) have been selected according to two main principles: a) existence of some regulations in building acoustics; b) interest and motivation to discuss such regulations and apply ISO standards. Besides, these three selected countries represent a high percentage of the population in South America. Adding the population and surface of these three countries it comes to approximately 64 % of the population and about 68% of the surface of South America. Several other well populated countries like Peru, Colombia and Bolivia (7.5, 11.6 and 2.4% of the population in South America respectively) do not have any legislation concerning sound insulation in buildings and could not be included in this pilot study.

Table 4 summarizes relevant data considering population, dwellings and percentage of people living in urban spaces (urban population density) since it is mainly in urban environment where noise in housing is a major problem.

Table 4: Geographical data and population distribution in selected countries

Country	Population (millions)	Area (10^3 km^2)	Population density (inhabitants/km^2)	No. of dwellings (millions)	Urban population (millions)	Urban population density (%)
Argentina [1]	43	2780	16	14	39.4	92
Brazil [2]	206	8515	25	44.7	176	85
Chile [3]	18	756	24	5.5	15.8	89
Austria [4]	8.5	84	104	4.4	56.3	66
Belgium [4]	11.2	31	371	5.3	10.9	98
Czech Rep. [4]	10.5	79	136	4.7	7.6	73
Denmark [4]	5.6	43	133	2.8	4.9	88
Spain [4]	46.5	506	93	25.2	36.8	79

3 Acoustic regulations - purpose and typical main contents

The main purpose of implementing acoustic regulations is in general the protection of the health of the citizens whether at work, in the urban environment, in leisure spaces, in their homes or in a learning situation. The impact of noise on health has been evidenced by many researchers and recognized by the WHO and other similar organizations in different publications; see e.g. [1], [2], [3].

Acoustic regulations aim at protecting citizens from noise, and for schools a secondary objective is optimization of listening conditions, thus improving learning and work conditions in educational environments.

Typical acoustic regulations include limit values for airborne and impact sound insulation, façade sound insulation and/or maximum sound levels indoors, noise limits for traffic and service equipment as well as limits for reverberation time and/or absorption area.

Previously, comparative studies of sound insulation requirements and descriptors in more than 30 countries in Europe have been carried out; see [4], [5], [6]. Most regulations refer to the international ISO measurement and rating methods, which are also implemented as European standards and as national standards as well. These studies revealed a wide variety of sound insulation descriptors and requirements. Further considerations on the evolution of the international regulatory framework within building acoustics is found in [7].

Traditionally sound insulation measurements were made according to the ISO 140 series, although over the last 6 years the series has been replaced by new standards. Some countries

[1] Censo Nacional de Población, Hogares y Viviendas 2010- Censo del Bicentenario -Resultados definitivos, Serie B Nº 2 -Instituto Nacional de Estadística y Censos (INDEC)- Buenos Aires, octubre de 2012

[2] Instituto Brasileiro de Geografia e Estatística
http://www.ibge.gov.br/home/estatistica/populacao/censo2010/entorno/entorno_tab_zip_xls.shtm

[3] Informe final Comisión Externa Revisora del CENSO 2012- Instituto Nacional de Estadística de Chile - http://www.ine.cl/canales/chile_estadistico/familias/censos.php

[4] Eurostat http://ec.europa.eu/eurostat

have updated their regulations accordingly while most countries are on the way of doing it. The final restructuring of the standards directly related to acoustic regulations is shown in Tables 1 and 2. ISO 140-2 about precision has been replaced by ISO 12999.

Table 1: Measurement standards for laboratory sound insulation measurements

LABORATORY MEASUREMENTS								
Withdrawn	ISO 140-1	ISO 140-3	ISO 140-6	ISO 140-8	ISO 140-10	ISO 140-11	ISO 140-16	ISO 140-18
Replaced by	ISO 10140 parts 1 to 5							

Table 2: Measurement standards for field sound insulation measurements

FIELD MEASUREMENTS				
Withdrawn	ISO 140-4	ISO 140-5	ISO 140-7	ISO 140-14
Replaced by	ISO 16283 parts 1, 2 and 3			

Other field testing and rating standards commonly used are ISO 3382-2, ISO 10052, ISO 16032 and ISO 717. Table 3 summarizes present building acoustic regulations and sound insulation measurement methods for the selected countries.

Table 3: Acoustic regulations and sound insulation measurement methods in selected countries

	BUILDING ACOUSTIC REGULATIONS(1)	**MEASUREMENT METHODS(2)**
Argentina	IRAM 4044 -2015 (**R**) [8]	ISO 140 series both for lab and situ
Brazil	In NBR 15573 (**N**) [9]	ISO 140-4, -5, -7 (Engineering) ISO 10052 (Survey)
Chile	OGUC: Título 4 - Capítulo 1, Artículos 4.1.5 y 4.1.6 (**N**) [10], [11]	ISO 140 series both for lab and situ
Austria	[12], [13]	ISO 140-4, -5, -7
Belgium	[14], [15]	ISO 140-4, -5, -7
Czech Rep	[16]	ISO 140-4, -5, -7
Denmark	[17]	ISO 140-4, -5, -7
Spain	CTE-DB HR (**N**) [18]	ISO 140-4, -5, -7
(1) **R =** Recommended; **N =** Normative (2) The field standards ISO 140-4, -5, -7 have now been replaced by the ISO 16283 series, the last part being published spring 2016, and implementation is expected in many countries soon.		

4 Acoustic regulations for housing

Tables 5 and 6 summarize the sound insulation requirements found in the existing regulations in the eight selected countries. Table 5 relates to protection against neighbouring noise, whereas Table 6 is focused in other sound sources in a dwelling such as outdoor noise or service equipment, among other things. The values included in these tables are the basic limit values, not considering special cases like higher quality spaces or especially noisy spaces.

Concerning neighbour noise and airborne sound insulation, there is a significant wide spread both considering requirements and descriptors: there are four different descriptors (R'_w, R_A/R'_A, $D_{nT,w}$, $D_{nT,A}$) and requirements varying from 55 to 45 dB. The frequency range is not

homogeneous either, since at least in Spain the upper frequency range reaches 5000 Hz instead of 3150 Hz found in ISO 717-1. For impact sound insulation there are only two different descriptors ($L'_{n,w}$, $L'_{nT,w}$), but the requirements range from 48 to 80 dB. In this case these extreme requirements are set for the same impact sound insulation descriptor, $L'_{nT,w}$, which allows making a direct comparison and concluding that in Brazil the impact sound insulation requirement is 32 dB weaker than in Austria. Although it is not possible to make a direct comparison of requirements when different descriptors are applied, it is nevertheless clear that there are significant differences between countries as far as requirements are concerned. The background an details for these requirements should be investigated further.

Table 5 – Sound insulation requirements for multi-family housing

Sound insulation between dwellings in multi-family housing – Requirements[(1),(2),(3)] – March 2016			
Country	**Airborne Requirement [dB]**	**Impact Requirement [dB]**	**Comments**
Argentina	$R'_w \geq 50$	$L'_{n,w} \leq 53$	Not mandatory. Approved November 2015
Brazil	$D_{nT,w} \geq 45$	$L'_{nT,w} \leq 80$	Mandatory
Chile	R_A / $R'_A \geq 45$	$L_{n,w} \leq 75$	Mandatory. Under revision. Proposal 2014: $R'_w + C \geq 50$ dB; $L'_{n,w} \leq 65$ dB.
Austria	$D_{nT,w} \geq 55$	$L'_{nT,w} \leq 48$	Stricter requirements for row housing
Belgium	$D_{nT,w} \geq 54$	$L'_{nT,w} \leq 58$	From “non-bedrooms” outside the dwelling to a bedroom ≤ 54 dB is required.
Czech Rep.	$R'_w \geq 53$	$L'_{n,w} \leq 55$	
Denmark	$R'_w \geq 55$	$L'_{n,w} \leq 53$	
España (Spain)	$D_{nT,A}^* \approx D_{nT,w} + C \geq 50$	$L'_{nT,w} \leq 65$	* $D_{nT,A}$ from 100 Hz to 5000 Hz
Notes - General (1) Overview information only. Detailed requirements and conditions are found in the building codes. (2) No generally applicable conversion between the different descriptors exists, as the relations depend on characteristics of rooms and constructions. Exact conversion can only be made in specific cases. (3) Main requirements only. Typically, there are stricter requirements towards e.g. noisy premises.			

One reason for the differences observed in Table 5 could be that countries with a longer history/experience on sound insulation regulations have developed stronger requirements as well as building techniques to comply with such requirements, whereas countries “younger” in this field have less strong requirements. On the other hand, there might also be other cultural and/or climatological reasons. Examples of corresponding sound insulation requirements for other countries in Europe are found in [4], [5], [6].

As previously mentioned, Table 6 gathers other aspects related to protection against noise, not directly related to neighbour noise, but to outdoor noise, service equipment noise and reverberation time in common areas. When considering protection against outdoor noise, regulations often include requirements either for the façade sound insulation or for maximum noise levels indoors. For the selected countries, the descriptors and limit values vary considerably. For example in Argentina, the requirements are for the façade parts, independently of the type/level of noise source outdoors, in Spain the requirement is also for the façade but dependent on L_{den} outdoors (defined in [19]), in Denmark the requirement is set to the L_{den} indoors and in Belgium and Czech Republic the requirement is set for $L_{A,eq}$. For

service equipment in most cases the regulations include a limit for stationary sources and another for maximum or peak values, but again, the wide spread of descriptors and how they shall be measured is considerable and needs further investigation. Concerning the reverberation time in common areas, among the selected countries, there are only two (Denmark and Belgium) which include a requirement for reverberation time in stairwells. These requirements intend to reduce the noise in such common areas and thus protect from noise the spaces adjacent to them, although the two countries have chosen a different approach for the requirement: Denmark has set an upper limit for the reverberation time, whereas in Belgium the requirement is expressed as minimum sound absorption depending on the walkable areas.

Table 6 – Other acoustic requirements for multi-family housing - Examples

Other acoustic requirements(1)(2) for multi-family housing - March 2016				
Country	**Façade sound insulation or indoor level Req. [dB]**	**Service equipment noise Req. [dB]**	**Reverberation time in stairwells Req. [s]**	**Comments**
Argentina	$D_{2m,n,T,w} \geq 53$* $D_{2m,n,T,w} \geq 36$**	Recommendations on mounting	None	* For “blind” walls ** For glass areas (max 20% of façade)
Brazil	$D_{2m,n,T,w} \geq$ 20-30*	$L_{Aeq,NT} \leq 37$** $L_{ASmax,NT} \leq 42$**	None	* Depending on surrounding noise **Recommendations for water supply devices, not mandatory
Chile	$D_{nT,w} + C_{tr} \geq X$*	$L_{A,max} < 40$ inside dwelling	None	Proposal 2014 (not yet approved) * X depending on outdoor noise For Leq (h) < 60 dB(A) $\Rightarrow$ X= 20
Austria	$R'_{res,w} \geq X$*	Stationary sources: $L_{AFmax,nT} \leq 25$ Short-term: $L_{AFmax,nT} \leq 30$	None	* X depends on outdoor level For 61 <L_d < 65 and 51 <L_n < 55 dB $\Rightarrow$ X= 43
Belgium	Goal indoor level $L_{A,eq}$ max 34 dB during peak hours. Always: $D_{nA,tr} \geq 26$	$L_{Ainstal,nT} \leq 35$ (stationary sources)	$A_w \geq 0.3 \times S_H$ *	* S_H = Surface of horizontal projection of walkable areas
Czech Rep.	Indoor level: $L_{A,eq} \leq 40$ (day) $L_{A,eq} \leq 30$ (day)	$L_{A,max} \leq 40$ (day) $L_{A,max} \leq 30$ (night)	None	
Denmark	$L_{den} \leq 33$	$L_{A,eq} \leq 30$	T ≤ 1.3 sec *	* 500 Hz, 1 kHz, 2 kHz
España (Spain)	$D_{2m,nT,Atr\ (100\ to\ 5000)} \approx D_{2m,nT,w} + C_{tr} \geq X$*	Recommendations on mounting	None	* X depending on L_{den} For L_{den} < 60 dBA $\Rightarrow$ X= 30
Notes - General (1) Overview information only. Detailed requirements and conditions are found in the building codes (2) No generally applicable conversion between the different descriptors exists, as the relations depend on characteristics of the situation, e.g. rooms, constructions or sources.				

The differences found in acoustic regulations for housing both within the same continent and between continents point at the need for creating common discussion forums which in turn will support the optimal development and update of building acoustics regulations according to the specificity and needs in each country, but aiming at harmonizing the “language” used in this field. The effect of cultural and climatological aspects on building sound insulation requirements would nevertheless be part of a different study.

5 Acoustic regulations for schools

In educational buildings, it is of high importance that the hearing/listening conditions are optimized to facilitate the learning process. For the same selected countries, airborne and impact sound insulation requirements for classrooms are summarized in Table 7. All countries, except Brazil and Chile, have included in regulations airborne and impact sound insulation requirements for classrooms and the situation of finding different descriptors and requirements is similar to the one described in section 4 for housing. Looking at the data in table 7, there are three countries (Argentina, Czech Republic and Denmark) which have chosen similar airborne sound insulation descriptor and requirement: $R'_w \geq 47/48$ dB for walls. On the other hand, if $D_{nT,w}$ +C is considered, there are differences of about 6 dB between countries. For impact sound insulation, the higher divergences are found for example between Spain ($L'_{nT,w} \leq 65$) and Austria ($L'_{nT,w} \leq 48$), with 17 dB difference for the same type of requirement.

The differences found concerning airborne and impact sound insulation in classrooms indicate the need of research and discussion on the subject. It is interesting to notice that when comparing tables 7 and 4, some regulations consider the classrooms just like a protected space in a dwelling whereas others have slightly lower requirements than for dwellings. The different approaches found in the regulations motivate the following questions: Are the sound insulation needs in a classroom the same as in a private space in a dwelling or not? Do needs for schools differ between countries? Do needs for housing differ between countries?

Table 7 – Sound insulation requirements for schools – Between normal classrooms

Sound insulation requirements for schools – Between normal classrooms[(1),(2),(3)] – March 2016			
Country	**Airborne Req. [dB]**	**Impact Req. [dB]**	**Comments**
Argentina	$R'_w \geq 47$	$L'_{n,w} \leq 53$	
Brazil	None	None	
Chile	None	None	
Austria	$D_{nT,w} \geq 55$	$L'_{nT,w} \leq 48$	
Belgium	$D_{nT,w} + C \geq 44$	$L'_{nT,w} + C_I \leq 60$	
Czech Rep.	R'_w H: ≥ 47; V: ≥ 52	$L'_{n,w} \leq 58$	
Denmark	R'_w H: ≥ 48; V:≥ 51	$L'_{n,w} \leq 58$	
España (Spain)	$D_{nT,A}$* ≈ $D_{nT,w} + C \geq 50$	$L'_{nT,w} \leq 65$	* $D_{nT,A}$ from 100 to 5000 Hz
Notes - General (1) Overview information only. Detailed requirements and conditions are found in the building codes. (2) No generally applicable conversion between the different descriptors exists, as the relations depend on characteristics of rooms and constructions. Exact conversion can only be made in specific cases (3) Typically stricter requirements apply in case of rooms for music, singing, woodwork.			

As for housing, there are other acoustic requirements to be considered, when protecting students from noise: façade sound insulation, service equipment and reverberation time in the class room. The reverberation time is of high importance since it has been shown that there is a strong correlation between the reverberation time and speech intelligibility in a classroom. - Table 8 summarizes these requirements for the selected countries. Concerning protection

against outdoor noise, the requirements for classrooms are similar to those for dwellings (cf. Tables 6 and 8). Concerning reverberation time and service equipment noise, the selected countries in Europe have a requirement for classrooms, except equipment noise in Spain. In South America, only Chile has a requirement for equipment noise, and Brazil has a recommendation for reverberation time.

Table 8 – Other acoustic requirements for schools than sound insulation - Examples

Other acoustic requirements for schools[(1),(2)] – Normal classrooms – March 2016				
Country	Façade sound insulation or indoor level **Req. [dB]**	Service equipment noise **Req. [dB]**	Reverberation time (furnished, unoccupied)	**Comments**
Argentina	$D_{2m,n,T,w} \geq 53$* $D_{2m,n,T,w} \geq 36$**	None	None	* For "blind" walls ** For glass (max 20% of façade)
Brazil	None	None	0.6 s*	* FDE recommendations. Not normative.
Chile	$D_{nT,w} + C_{tr} \geq X$*	$L_{A,max} < 40$ inside classroom	None	* X depending on outdoor noise Leq (h) and type of building
Austria	$R'_{res,w} \geq X$*	Stationary sources: $L_{AFmax,nT} \leq 25$ Short-term: $L_{AFmax,nT} \leq 30$	$T_{max} = 0.32 \log V - 0,17$ for occupied rooms **, e.g. for V = 150 m^3: T ≤ 0.5 s	* X depends on outdoor level For 61 < L_d < 65 and 51 < L_n < 55 dB ⇒ X=43 ** T_{max} depends on room volume
Belgium	Depends on outdoor level. $D_{nA,tr} \geq 26$	$L_{Aeq,nT,stat} \leq 35$ (stationary sources)	Example V = 150 m^3: T ≤ 0,8 s*	* T_{max} depends on room volume Avg. of 500, 1000, 2000 Hz.
Czech Rep.	$L_{A,eq} \leq 45$	$L_{A,max} \leq 45$	T ≤ 0.7 s* (125 Hz - 4 kHz)	* Target value. For 250-2000 Hz, lower/upper limits are 80/120 %.
Denmark	$L_{den} \leq 33$	$L_{A,eq} \leq 30$	T ≤ 0.6 s *	* 125 - 4000 Hz
España (Spain)	$D_{2m,nT,Atr} \approx D_{2m,nT,w} + C_{tr} \geq X$*	None	T ≤ 0.5 s furnished T≤ 0.7 s unfurnished	* X depending on L_{den} * $D_{2m,n,T,Atr}$ from 100 to 5000 Hz
Notes - General (1) Overview information only. Detailed requirements and conditions are found in the building codes. (2) No generally applicable conversion between the different descriptors exists, as the relations depend on characteristics of the situation, e.g. rooms, constructions or sources.				

6 Conclusions

Based on the research done within this pilot study, it has been found that there are significant differences concerning acoustic regulations between Europe and South America and even within each of these regions.

On one hand it is important to point out that in South America, there are still many countries not having acoustic regulations. On the other hand, the existing regulations, both in Europe and South America, are not easily comparable since they are quite inhomogeneous in contents. Some countries in South America have regulations for dwellings only; others include schools. In general, different descriptors and requirement levels are found. On top of the aforementioned differences, there are other discrepancies not included in this paper, e.g. in procedures verifying compliance with the requirements.

Concerning dwellings, apart from the previously mentioned different descriptors and different levels of requirements, it has been observed that some countries include regulations for service equipment and reverberation time in stairwells, while others don't. In general, the requirements are lower in Southern Europe (cf. also [6]) and South America than in Central and Northern Europe. The reasons for these differences are beyond the scope of this paper, but could partially be related to cultural, historical and even geographical and climatic aspects.

When it comes to acoustic regulations in schools, the most important finding is that not all existing regulations include requirements for schools and, when they do, the inhomogeneity is very significant. None of the countries in South America have a requirement for reverberation time in classrooms, although very important for speech intelligibility and the learning process, especially for children. However, Brazil has a recommendation, which is a step in the right direction.

Having observed the existing differences between acoustic regulations in the selected countries and between Europe and South America in general, it is important to react and promote discussion at both ends. The future challenges both in Europe and South America are similar: aiming at harmonizing sound insulation descriptors, aiming at reviewing and improving acoustic performance of buildings, aiming at developing basic acoustic regulations, where needed, and finally, aiming at enforcing the compliance with the regulations. Considering this set of challenges, an ultimate step would be creating awareness among authorities and building industry and developing a common acoustic classification scheme for dwellings and other buildings that could be used not only for new-build, but also to quantify acoustic performance of existing and retrofitted buildings.

This is especially interesting now, when still many countries both in Europe and South America are in the process of developing or updating their respective acoustic regulations. It is not often that collaboration between experts at an early stage is possible. The findings of the pilot study should be looked upon as an incentive for discussing and understanding acoustic regulations and for initiating collaboration about reviewing, revising and harmonizing requirements, aiming at in the long run to improve acoustic quality of new and retrofitted buildings.

Acknowledgments

The authors would like to thank all the acoustic colleagues who have assisted collecting updated information concerning building acoustics regulations in their country. Without their collaboration this study would not be possible. For all countries, comments, corrections and updated information will be highly appreciated.

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