

# A COMPARISON OF BUILDING REGULATIONS ACROSS EUROPE

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## 1 INTRODUCTION

As part of a study of different Building Regulations across Europe<sup>1</sup>, requirements for acoustics performance were investigated in Belgium, Denmark, England and Wales, France, Germany, Netherlands, Norway and Sweden. Indeed acoustics requirements were defined to control unwanted noise coming from domestic activities, from equipment within or outside the building and from the environment.

This paper is an opportunity to show the differences in noise control requirements across eight European countries. The internal noise level is investigated in the first part of the paper, then airborne and impact sound transmission in the second and third parts respectively.

## 2 INTERNAL NOISE LEVELS

### 2.1 Indices

$L_{Aeq}$	Equivalent continuous A-weighted sound pressure level
$L_{Aeq\ 24h}$	Standard equivalent continuous A-weighted sound pressure level normalised to 24hours.
$L_{pA}$	A-weighted sound pressure level
$L_{nAT}$	A-weighted continuous sound pressure level, normalised over a period of time T
$L_{In}$	A-weighted sound pressure level
$L_{Afm\max}$	Maximum instantaneous A-weighted sound pressure level with fast time weighting
$L_{A\max}$	Maximum momentary A-weighted sound pressure level
$L_{pAF\max}$	Maximum A-weighted sound pressure level with fast time weighting
$L_r$	A-weighted sound pressure averaged over the duration of noise exposure. 'Single event' noises are taken account when measuring $L_r$ .
$L_{i,A}$	Averaged A-weighted standardised sound pressure level over 5 octave bands 125, 250, 500, 1000, and 2000Hz

### 2.2 Internal noise level requirements

	Types of installations	Internal noise level from equipment	
		Situations	Requirement
<b>Belgium</b>	External noise. Noise within the building but external to the room to be protected.	Living spaces	Category 1 $L_{Aeq} = 30dB$ , Category 2 $L_{Aeq} = 35dB$ , Category 3 $L_{Aeq} = 40dB$ , Category 4 $L_{Aeq} = 45dB$ For existing background noise $L_{Aeq} \geq 27dB$ : difference between the noise source and background noise = 6dB

Table 1-a: Internal noise level requirements

	Types of installations	Internal noise level from equipment	
		Situations	Requirement
<b>Belgium</b>  <i>Code wallon de l'Aménagement du territoire, de l'Urbanisme et du Patrimoine</i>	<p>NBN S01-400 defines four categories of development areas with differing requirements for building acoustics: Category I: rural or suburban residential areas; Category II: Urban residential areas; Category III: Areas affected by light industries, and housing in commercial areas; and Category IV: Town centres, areas affected by heavy industries and areas within 5km of an airport.</p> <p>There are also noise limits on technical spaces in dwellings, by reference to Noise Rating criteria (NR):</p>	Bedrooms	Category1 $L_{Aeq} = 30\text{dB}$ Category2 $L_{Aeq} = 30\text{dB}$ Category3 $L_{Aeq} = 35\text{dB}$ Category4 $L_{Aeq} = 40\text{dB}$ For existing background noise $L_{Aeq} \geq 27\text{dB}$ : difference between the noise source and background noise = 3dB
<b>Denmark</b>  <i>Building Regulations BR-95 (1995)</i>  <i>Building Regulations for Small Dwellings BR-S 98 (1998)</i>	<ul style="list-style-type: none"> <li>- Drainage, ventilations, or heating equipment, waste disposal units, etc.</li> <li>- Utility water equipment, installations for operation of windows, sunscreens.</li> <li>- Drainage and utility water equipment, lifts, ventilation systems, heating systems, macerators, equipment in common service rooms, e.g. laundry-rooms, kitchens; excludes noise from utility water installation in dwelling itself.</li> <li>- Installations in commercial units in domestic buildings</li> <li>- Heating and ventilation, mechanical refuse collection systems.</li> </ul>	<p><u>Small buildings:</u></p> <ul style="list-style-type: none"> <li>- Habitable rooms, kitchens:</li> </ul> <p>- Neighbouring houses</p> <p><u>Multi-storey domestic buildings:</u></p> <ul style="list-style-type: none"> <li>- Habitable rooms, kitchens:</li> </ul> <p>Habitable rooms</p> <p>At windows, in recreation areas (balconies, roof terraces, conservatories etc.)</p>	$L_{Aeq} = 30\text{dB}$ $L_{Aeq} = 25\text{dB}$ (momentary sounds such as motors starting or stopping; noise with a pure tone such as whistle from a fan) $L_{Aeq} = 30\text{dB}$  $L_{Aeq} = 30\text{dB}$  $L_{Aeq} = 30\text{dB}$ $L_{Aeq} = 40\text{dB}$
<b>England &amp; Wales</b>  <i>Approved Document E (2003)</i>	—	—	—
<b>France</b>  <i>Code de la Construction et de l'Habitation (CCH)</i>  <i>Arrêté 30.6.99</i>	<ul style="list-style-type: none"> <li>- Heating or air-conditioning unit</li> <li>- Heating appliance unit operating at minimal power</li> <li>- Mechanical ventilation installation at minimum setting</li> <li>- Common equipment, such as lifts, heating plant, transformers, pumps</li> <li>- Individual appliance in a dwelling</li> </ul>	Principal rooms Kitchens Principal room open plan with kitchen Principal rooms Kitchens of each dwelling  Principal rooms Kitchens	$L_{nAT} = 35\text{dB}$ $L_{nAT} = 50\text{dB}$ $L_{nAT} = 40\text{dB}$  $L_{nAT} = 30\text{dB}$ $L_{nAT} = 35\text{dB}$   $L_{nAT} = 30\text{dB}$ $L_{nAT} = 35\text{dB}$
<b>Germany</b>  <i>Hessische Bauordnung (HBO)</i> <i>DIN 4109</i>	<ul style="list-style-type: none"> <li>- Water and waste water installations</li> <li>- Noise from business activities, plants.</li> </ul>	Living room, bedroom	$L_{In} = 35\text{dB}$ $L_{AFmax} = 30\text{dB}$ $L_r = 35\text{dB}$ (6:00 to 22:00) $L_r = 25\text{dB}$ (22:00 to 06:00) +10dB for brief peaks
<b>Netherlands</b> Bouwbesluit (Building Decree) (2001) <i>NEN 5077</i>	Flush toilets, taps, mechanical ventilation systems, hot water equipment, equipment to increase water pressure, lifts.	Habitable area of user function on adjacent plot. Non-shared habitable area of another living function on the same plot.	Characteristic sound level $L_{i,A} = 30\text{dB}$ (new build); $L_{i,A} = 40\text{dB}$ (adaptation or extension of existing buildings)

Table 1-b: Internal noise level requirements

	Types of installations	Internal noise level from equipment	
		Situations	Requirement
<b>Norway</b>  <i>Tekniske forskrifter til plan- og bygningsloven av 14. juni 1985 nr. 77</i>	Lifts, escalators, fans, sanitary appliances, air conditioning plants, installations for service or commercial purposes: washing machines (common laundry rooms), refrigeration machines (shops), production machinery (industry) etc. Noise from use and running of indoor car parks.	Bedrooms, rooms for occupation (excluding storage rooms, toilets, bathrooms, hallways and corridors).  Also, limits on noise nuisance from equipment to outdoor areas intended for recreation or play.	$L_{A\text{ eq }24\text{h}} = 30\text{dB}$ $L_{A\text{ max}} = 32\text{dB}$  $L_{A\text{ max}} = 40\text{dB}$
<b>Sweden</b>  <i>Boverkets byggregler BFS 1998:38 (1999)</i>	Building services.	<u>Sounds not from within same dwelling:</u> Bedrooms, living rooms in non residential premises, Sound of long duration Sound of short duration Kitchens: Sound of long duration Sound of short duration	$L_{pA} = 30\text{dB}$ $L_{pAF\text{ max}} = 35\text{dB}$  $L_{pA} = 35\text{dB}$ $L_{pAF\text{ max}} = 40\text{dB}$

*Sounds of short duration include sound due to pressure pulses or flow of water in water supply and drainage installations, impulse sound due to the starting and stopping of lifts; sounds of long duration include sound from ventilation plants, refrigerator compressors, heat pumps.*

Table 1-c: Internal noise level requirements

With the exception of the building regulations of England and Wales, which do not take account internal noise levels due to appliances and services, the other countries consider the noise level of living rooms, bedrooms, American kitchens and rooms facing noisy areas e.g. Denmark. The dB(A) index is employed to evaluate the noise level in housing, which are mainly central heating, wastewater installation, lifts, air-conditioning and washing machines. The single and maximum values are either measured instantaneously or over a period of time which can differ between countries. In Sweden, sound of short duration and long duration are considered, but that will be replaced in the future regulations by considering internal noise levels including low frequency. The noise level index employed in Netherlands differs to those used in the other countries but is likely to change in the next regulations. Noise level required in living rooms and bedrooms is around 30dB(A) while the level in less sensitive rooms can be equal or higher than 30 to 50dB(A) e.g. in kitchen, bathrooms. Most of the countries consider noise from ventilation, boilers, washing machine, drainage and lifts. Some differences in requirements, however, can be observed: In Germany, the noise from business activity plants is taken into account and should be lower than 35dB(A) in living room and bedroom. A distinction is also made between noise level in the daytime and night time. In Denmark,  $L_{Aeq}$  is modified by an extra 5dB if the noises contain audible tone or pulses and by 3dB if the room is furnished. Noise requirements might vary if the building is a house or apartment block or a house placed in a more or less noise sensitive area. It was also observed that despite no requirements for internal noise level in England and Wales, the Approved Document E contained guidance for the type of walls separating a habitable room or kitchen and a refuse chute. In this case, the wall and the finishes should have a mass per unit area of at least of 1320 kg/m<sup>2</sup>.

### 3 AIRBORNE SOUND INSULATION

#### 3.1 Indices

**R** Sound reduction index: characterises the sound insulation characteristics of a wall or floor; R is measured in a laboratory, where the source room and receiving room are isolated, with no flanking transmission.

<b>R'</b>	Apparent sound reduction index, measured in the field, where there may be flanking transmission between the two rooms.
<b>D<sub>n</sub></b>	Level difference between the source room and the receiving room, measured in the field.
<b>D<sub>nA</sub></b>	Level difference corrected by the standard absorption area of $A=10\text{m}^2$ for the receiving room.
<b>D<sub>nT</sub></b>	Standardised level difference, i.e. $D_n$ corrected by the standard reverberation time $T$ of the receiving room.

The different indices, measured from 100Hz to 3150Hz, can be characterised by a single value number, which is estimated by comparing the measured curve to reference curves given in EN ISO 717-1:

<b>R<sub>w</sub></b>	Weighted sound reduction index, laboratory measurement
<b>R'<sub>w</sub></b>	Weighted apparent sound reduction index, field measurement. This may be corrected by the correction terms $C$ or $C_{tr}$ :
<b>D<sub>nT,w</sub></b>	Weighted standardised level difference, field measurement. This may be corrected by the correction terms $C$ or $C_{tr}$ :
<b>D<sub>nT,A</sub></b>	Weighted standardised level difference measured with 'pink noise' in dB(A), field measurement: $D_{nT,A} = D_{nT,w} + C$
<b>D<sub>nT,A,tr</sub></b>	Weighted standardised level difference using the traffic noise correction term, field measurement: $D_{nT,A,tr} = D_{nT,w} + C_{tr}$

The correction term **C** is appropriate to speech, music, radio, TV, noise from children playing, and for some outdoor noise such as medium and high frequency noise from factories, or noise from motorways with traffic faster than 80km/h. **C<sub>tr</sub>** is appropriate to noise such as urban traffic, trains at low speed, aircraft, night-club music, or low and medium frequency noise from factories.

### 3.2 Airborne sound insulation requirements

	Situations	Requirements
<b>Belgium</b>	For dwellings and dwellings in multi-storey buildings: - From common circulation to bedroom - From common circulation to living room - From common circulation to kitchen or playroom NBN S01-401 has charts relating values to Categories, but they are difficult to interpret. A range of values is given, corresponding to classes A (recommendations for acoustic comfort) and B (minimum requirements).	$D_n$ = Category I $D_n$ = Category II $D_n$ = Category III
<b>Denmark</b>	<b>Multi-storey residential buildings:</b> Between dwellings and: - other dwellings, common spaces:  - noisy premises: * - common rooms:  * Premises producing particularly disturbing noise include boiler rooms, laundries, banqueting rooms, hobby-rooms, business premises, workshops, and restaurants. <b>Joined houses:</b> - between houses, between houses and common spaces: - between dwellings and common spaces:	$R'_w$ = 52dB (walls); $R'_w$ = 53dB (floors);  $R'_w$ = 60dB $R'_w$ = 32dB (doors)   $R'_w$ = 55dB (walls) $R'_w$ = 32dB (doors)
<b>France</b>	<u>Between place in dwelling (except garage) and room in another dwelling:</u> - principal rooms - kitchens, bathrooms <u>Between common internal circulation spaces and room in dwelling in building:</u> - principal rooms separated by landing door: - principal rooms in other situations: - kitchens, bathrooms separated by landing door: - kitchens, bathrooms in other cases: <u>Between individual or communal garage and room in other dwelling:</u> - principal rooms - kitchens, bathrooms	[NB: $D_{nT,A} = D_{nT,w} + C$ ]  $D_{nT,A} = 54\text{dB(A)}$ $D_{nT,A} = 51\text{dB(A)}$  $D_{nT,A} = 40\text{dB(A)}$ $D_{nT,A} = 53\text{dB(A)}$ $D_{nT,A} = 37\text{dB(A)}$ $D_{nT,A} = 50\text{dB(A)}$  $D_{nT,A} = 55\text{dB(A)}$ $D_{nT,A} = 52\text{dB(A)}$

Table 2-a: Airborne sound insulation requirements

	Situations	Requirements
France	<u>Between activity spaces and room in other dwelling:</u> - principal rooms - kitchens, bathrooms	$D_{nT,A} = 58\text{dB(A)}$ $D_{nT,A} = 55\text{dB(A)}$
England and Wales	- Separating walls and floors and stairs for dwelling-houses and flats and floors and stairs for rooms for residential purpose - Separating walls, floor and stairs for dwelling-houses, flats and also rooms for residential purposes) - Separating walls (rooms for residential purposes)  - Internal walls and floors (within dwelling-houses, flats and rooms for residential purposes)	$D'_{nTw} + C_{tr} = 45\text{dB}$ (purpose built) $D'_{nTw} + C_{tr} = 43\text{dB}$ (formed by material change of use) $D'_{nTw} + C_{tr} = 43\text{dB}$ (purpose built) $R_w = 40\text{dB}$ (purpose built or formed by material change of use; laboratory values)
Germany	<u>Separating walls between houses</u> Walls between neighbouring flats Between dwellings in multi-storey buildings Floors between neighbouring flats; passages, cellars, under bath / WC. Walls of stairwells	$R'_w = 57\text{dB}$ $R'_w = 53\text{dB}$ $R'_w = 55\text{dB}$ $R'_w = 54\text{dB}$ $R'_w = 52\text{dB}$
Netherlands	<u>From a closed room to a habitable area</u> - in adjacent user function on another plot (except light industrial or unspecified user function) - in adjacent living function on the same plot * (except between common rooms serving the same user functions)  <u>From a closed room to a closed room that is not a habitable area</u> - in adjacent user function on another plot - in adjacent living function on the same plot * (except transmission to circulation space, or between common rooms serving the same user functions)  * Insulation of adjacent user functions on the same plot only applies to dwellings ** Approximate equivalent values calculated using ISO 717 part 1 and ISO 717 part 2: $I_{lu} \equiv D_{ntw} + C - 51\text{dB}$ ; $I_{co} \equiv 59 - L'_{n,w} + C_l$	New build: $I_{lu} = 0\text{dB}$ $[\equiv D_{ntw} + C = 51]^{**}$  Adaptations, extensions: $I_{lu} = -10\text{dB}$ $[\equiv D_{ntw} + C = 61]^{**}$  New build: $I_{lu} = -5\text{dB}$ $[\equiv D_{ntw} + C = 46\text{dB}]^{**}$  Adaptations, extensions: $I_{lu} = -15\text{dB}$ $[\equiv D_{ntw} + C = 44\text{dB}]^{**}$
Norway	Between individual dwelling units; between communal areas (stairs lobby, corridors etc) and dwellings: Between commercial areas, car parks and dwellings:	$R'_w = 55\text{dB}$ $R'_w = 60\text{dB}$
Sweden	Between spaces outside dwelling and dwelling  Between dwellings, contiguous single family houses: Multi-storey blocks: Between spaces inside interior entrance doors and stairway / corridor, between dwelling and access balcony	$R'_w + C_{50-3150} = 52\text{dB}$ (wall) $R'_w = 53\text{dB}$ (floor) $R'_w = 55\text{dB}$ $R'_w + C_{50-3150} = 39\text{dB}$

Table 2-b: Airborne sound insulation requirements.

Most of the studied countries use the EN-ISO indices  $R'_w$  and  $D_{nTw}$  with the exception of Belgium and Netherlands. This is due to recent efforts made by member countries to unify the standards throughout Europe. Netherlands is actually on the way to change their indices for  $D_{nTw}$ . Airborne measurements are carried out in-situ according to ISO 140. France has recently changed their regulations to conform to measurements using white noise. The values for minimum requirement for airborne sound transmission between dwellings in Germany (for dwellings in multi-storey buildings), Norway and Sweden are around 55dB, but the requirement in Germany for walls between houses is slightly higher ( $R'_w = 57\text{dB}$ ). Denmark has the lowest requirements ( $R'_w = 52\text{dB}$ ).

Standardised level differences are used in England and Wales, Netherlands and France. The parameters used in the Netherlands and France are similar, but England and Wales use a different spectrum adaptation term  $C_{tr}$  to take into account the low frequencies which in France and

Netherlands are taken into account for facades only. The level of requirements in France is higher than those in Netherlands.

Requirements for walls in apartment blocks can differ to the walls of semi-detached or terraced houses (Denmark, Germany, Sweden). Requirements for walls in adaptations and extensions to existing buildings are often lower to those in new buildings due to the difficulties in quantifying flanking transmission. Specific requirements are given to take into account the effect of doors and commercial premises next to domestic walls. There are requirements to limit airborne sound transmission from common circulation spaces to dwellings in Belgium, Denmark, France, Norway, and Sweden and Germany. It looks like there are no similar specific requirements in Netherlands. Specific walls and doors are recommended to separate corridors and rooms in England and Wales to reduce flanking transmission and provide the appropriate sound insulation. Only France has specific requirements to limit sound transmission from garages to dwellings.

## 4 IMPACT SOUND INSULATION

### 4.1 Indices

$L_n, L_{nA}$	Normalised impact sound pressure level in the room, laboratory measurement; level corrected by the standard absorption area of the room
$L'_n, L'_{nA}$	Normalised impact sound pressure level in the room, field measurement; level corrected by the standard absorption area of the room
$L'_{nT}$	Standardised impact sound pressure level: sound pressure level in the room corrected by the standard reverberation time $T$ ; field measurement

The different indices, measured from 100Hz to 3150Hz, can be characterised by a single value number, which is estimated by comparing the measured curve to reference curves given in EN ISO 717-2

$L_{n,w}$	Weighted normalised impact sound pressure level; laboratory measurement; may be corrected by the correction terms $C_i$ :
$L'_{n,w}, L'_{nAw}$	Weighted normalised impact sound pressure level in the room corrected by the standard absorption area of the room; field measurement. This may be corrected by the correction terms $C_i$ :
$L'_{nT,w}$	Weighted standardised impact sound pressure level corrected by the standard reverberation time $T$ ; field measurement. This may be corrected by $C_i$ :

$C_i$  is an adaptation term used to translate the annoyance felt by the occupant of the house.

Obtained from ISO 717-2, its values is added to the impact noise indices in order to take account the unbalanced impact noise level representing the footstep noise.

### 4.2 Impact sound insulation requirements

	Situations	Requirements
Belgium	<u>Between dwellings in multi-storey buildings.</u>	
	- from kitchen / bathroom / playroom to bedrooms	$L_n$ = Category I
	- from bathroom / playroom to living room	
	<u>Between bedrooms</u>	$L_n$ = Category II
	- from bedroom to living room / kitchen	
	- from bedroom to living room	$L_n$ = Category II
	- from bedroom / living room / kitchen / bathroom / playroom to Kitchen	$L_n$ = Category III
	NBN S01-401 has charts relating values to Categories, but they are difficult to interpret. A range of values is given, corresponding to classes A (recommendations for acoustic comfort) and B (minimum requirements).	
Denmark	Multi-storey residential buildings: Habitable rooms and kitchens in surrounding dwellings and common spaces, from:	

Table 3-a: Impact sound insulation requirements

Denmark	Situations	Requirements
	<ul style="list-style-type: none"> <li>- floors, decks, roof terraces, access corridors, staircases, common corridors &gt; 2.5m<sup>2</sup>:</li> <li>- balconies, floors, and decks in bathrooms, WCs &gt; 2.5m<sup>2</sup>:</li> <li>- floors, decks in noisy premises</li> </ul> <p><i>* Premises producing particularly disturbing noise include boiler-rooms, laundries, banqueting rooms, hobby-rooms, business premises, workshops, restaurants.</i></p> <p><u>Joined houses:</u></p> <p>habitable rooms and kitchens: from</p> <ul style="list-style-type: none"> <li>- floors, decks, staircases</li> <li>- bathrooms, WCs &gt; 2.5m<sup>2</sup>.</li> </ul>	$L'_{n,w} = 58\text{dB}$ $L'_{n,w} = 63\text{dB}$ $L'_{n,w} = 48\text{dB}$ $L'_{n,w} = 53\text{dB}$ $L'_{n,w} = 58\text{dB}$
France	For all floors and walls in rooms except for balconies and loggias not immediately above an habitable room; for stairs in buildings having a lift, technical / service spaces:	$L'_{nT,w} = 58\text{dB}$
England and Wales	- Separating floors and stairs (dwelling-houses, flats, rooms for residential purposes)	$L'_{nTw} = 62\text{dB}$ (purpose built) $L'_{nTw} = 64\text{dB}$ (formed by material change of use)
Germany	<p><u>Between dwellings</u></p> <p><u>Between dwellings in multi-storey buildings</u></p> <p><u>From common space and stairs:</u></p> <ul style="list-style-type: none"> <li>- dwellings</li> <li>- dwellings in multi-storey building</li> </ul> <p>Floors between neighbouring flats; passages, cellars, under bath / WC.</p> <p>Stairs in stairwells in multi-family housing</p>	$L'_{n,w} = 48\text{dB}$ $L'_{n,w} = 46\text{dB}$ $L'_{n,w} = 53\text{dB}$ $L'_{n,w} = 58\text{dB}$ $L'_{n,w} = 53\text{dB}$ $L'_{n,w} = 58\text{dB}$
Netherlands	<p><u>From a closed room to a habitable area</u></p> <ul style="list-style-type: none"> <li>- in adjacent user function on another plot (except light industrial or unspecified user function)</li> <li>- in adjacent living function on the same plot * (except between common rooms serving the same user functions)</li> </ul>	<p>New build:</p> $I_{co} = 5\text{dB} [\cong L'_{n,w} + C_i = 54\text{dB}]^{**}$ <p>Adaptations, extensions:</p> $I_{co} = -5\text{dB}$ $[\cong L'_{n,w} + C_i = 64\text{dB}]^{**}$
Norway	<p>Between individual dwelling units; from communal areas (stairs lobby, corridors etc) to dwellings:</p> <p>From commercial areas, car parks to dwellings:</p> <p>From toilet, storage areas, balconies etc. to a dwelling unit:</p>	$L'_{nw} = 53\text{dB}$ $L'_{nw} = 48\text{dB}$ $L'_{nw} = 58\text{dB}$
Sweden	<p>In habitable rooms from stairway, corridor, access balcony:</p> <p>In habitable rooms from other space outside dwelling:</p> <p>In habitable rooms from stairway, corridor, access balcony:</p>	$L'_{nw} + C_{1,50-2500} = 64\text{dB}$ $L'_{nw} + C_{1,50-2500} = 58\text{dB}$ $L'_{nw} + C_{1,50-2500} = 64\text{dB}$

Table 3-b: Impact sound insulations requirements

As with airborne sound transmission, EN-ISO indices are used to characterise impact sound transmission index. The use of a tapping machine is consensual and measurements are done according to ISO 140. Distinctive requirements are made to the area of housing or type of housing, joined or apartment blocks in Belgium, Germany, Denmark and Sweden. The levels of requirements are greater for houses than flats. Germany has the highest requirement ( $L'_{n,w} = 46\text{dB}$ ) while Sweden has the lowest requirements ( $L'_{n,w} = 64\text{dB}$ ). The requirement in France ( $L'_{nTw} = 58\text{dB}$ ) is higher than in England & Wales ( $L'_{nTw} = 62\text{dB}$ ). Impact noise requirements only concern floors and stairs but not walls except in France. The adaptation term  $C_i$  is only taken into account by a few countries although other countries are on their way to integrate it in their building regulations. At present, Sweden and Netherlands only, consider  $C_i$ .

## 5 DISCUSSION AND CONCLUDING REMARKS

Although the studied countries refer to the same EN-ISO acoustics measurement standards, the comparison of acoustic regulations in acoustics shows a lack of uniformity, despite the efforts made over the past five years by some countries to change their indices and methods of measurement.

All values given for airborne, impact sound insulation and internal noise levels are requirements while they only are recommendations in Belgium. In addition, the description of recommended criteria in the national standards of Belgium is difficult to understand, due to its reference to categories of development and inclusion of both recommended and minimum levels. Furthermore, the interpretation of the charts showing related values to the categories of development is difficult to understand with confidence. Similar difficulties were encountered when considering the building regulations of Netherlands. The different requirements for dissimilar residential building quality classes, town houses or flats or for different rooms also makes the comparison uneasy and difficult to remember.

Recently, most of the studied countries are gradually adapting the spectrum adaptation term,  $C$ ,  $C_{tr}$  given in EN-ISO 717-1 and  $C_i$  given in EN-ISO 717-2. Forthcoming legislation in Sweden, Norway, Denmark, and Germany is expected to introduce them. However,  $C$ 's values are likely to differ across countries and England & Wales use  $C_{tr}$  for party walls and floors to take account of low frequencies while it is only used for facades in other European countries.

Some construction guidance is included in the building regulations to satisfy the requirements like in Germany, Denmark, Norway and England & Wales. There are generally no specific limitations on the choice of materials, with the exception of Germany where there is a prohibition on materials with poor acoustic properties. However, as shown by Grimwood<sup>2</sup>, poor workmanship and bad design often are the causes of raising noise complaints. To overcome these problems, Denmark requires pre-completion testing. However, often less than half of the new buildings are tested according to Danish consultants, with extra time and cost to the construction industry often given as the main reasons. England & Wales have introduced pre-completion tests, which may or may not take place depending on the outcome of the Robust Standard Details which must provide consistently good wall performance and so will not require pre-completion testing.

The study has also found that England & Wales, France and Germany have systems of labelling to describe certain aspects of the buildings performance, but it appears that only France has a label for the acoustics quality of new or converted buildings. The labelling agency *QUALITEL*<sup>3</sup> first makes a study based on calculations and requirements, then undertakes field measurements on at least 25 per cent of the completed buildings. Award of the *Confort Acoustique* label confirms that the field measurements agree with the levels of requirements in the building regulations.

All the building regulations are written in the native language, which makes the understanding very difficult when read by another European nationality. A duplicate of each building regulation written in English would create an easy access and better understanding of each requirement made by each country. The different indices and requirements also do not help European manufacturers to quantify their materials of construction using the same acoustic index. There is for example, no equivalent to Sabine's coefficient,  $\alpha$ , which is used to characterise the absorption properties of a material. The lack of a specific index, therefore, slows down the competitiveness between European manufacturers. Furthermore, the different indices and requirements across European countries place the architects and contractors in a very difficult position when they have construction sites in different countries. The units expressed as dB or dB(A) are also another common problem for architects to understand correctly. Five years ago, Carvalho<sup>4</sup> acknowledged the great disparity between the regulations. Since this time, some countries have made great efforts to reduce these differences but more work is required before obtaining the same acoustics Building Regulations across Europe.

## 6 REFERENCES

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