2004 CHANGES TO THE BCA – ARE THEY A STEP FORWARD?

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Abstract

The regulatory requirements affecting the acoustical quality of multiple occupancy buildings in Australia will change from mid 2004. This represents the first significant change to the acoustical requirements of the Building Code of Australia in eight years and, in fact, is the first change to technical performance standards imposed by the BCA since its commencement. The BCA was originally compiled as a redraft of regulatory standards existing at the time, such as Ordinance 70 in NSW. The new requirements are, therefore, the first substantial upgrade to regulatory building acoustic standards in Australia in over 30 years. This paper reviews the new BCA requirements in the context of other international building regulations and building design standards. The relevance of spectrum adaptation terms included in airborne and impact performance requirements is examined, as are the implications of those terms to common building construction materials. The priorities implied by the Code are compared with those expressed by apartment owner-occupiers. This examination aims to highlight the difficulties in some aspects of the new code with the intent that this may assist planners and other building regulators in the preparation of Local Environmental Plans and Development Control Plans.

Introduction

In May 2004 significant revisions to the acoustic provisions within the health and amenity section of the Building Code of Australia were introduced. This paper examines the technical requirements of those revisions for the most common application of multiple occupancy apartment buildings.

The new code has endeavoured to introduce fundamental changes with respect to sound isolation between apartments:

1. The structure of the BCA remains unchanged in stating an Objective (essentially to safeguard occupants from illness or loss of amenity), a Functional Statement that essentially requires a building to provide sound isolation properties, and Performance Requirements that essentially state that the those sound isolation properties must provide sufficient insulation to prevent illness or loss of amenity. This remains as a circular argument.
2. Revised 'deemed-to-satisfy' provisions are described elementally and require constructions providing airborne and impact sound isolation ratings, given in summary in Table 5, based on laboratory tests.
3. For airborne sound, verified performance standards are set 5dB lower than the laboratory 'deemed-to-comply' rating. The verified performance is stated as a field measured level difference (or noise reduction) and overcomes the uncertainty regarding the interpretation of performance requirements that existed under the previous BCA.
4. The field measured level differences and the laboratory ratings use the standard ISO weighting process but include standard spectrum adaptation terms discussed further below.
5. Impact noise isolation standards are expanded to include floor ratings based on weighted standardised impact noise level generation also including a spectrum adaptation term.
6. Verification methods are described but there appears to be no specification stating minimum verification requirements.
7. Overall, the acoustical performance standards required for building elements have been increased.

The revisions to BCA also introduce fundamental acoustic design and construction controls relating to services. These are:

1. The scope and requirements for acoustic treatments to services now formally include ductwork, water supply pipes, downpipes and electrical outlets in addition to the soil and waste pipes identified in the previous BCA issues.
2. Performance requirements are now specified, as laboratory tested constructions only, for the constructions surrounding duct, soil, waste, water supply and storm water pipes.
3. Design principles are included that impose a requirement for double-layer construction separating walls where water supply pipes pass in that wall, regardless of whether the wall is constructed of concrete, masonry or drywall.

One point of note is that reference in previous issues of the BCA to services addressed only the potential adverse effects of those services on the sound isolating properties of the dividing constructions (walls or floors) between dwellings. The terminology used in the 2004 issue code continues to explain these requirements almost unchanged, but gives examples that imply the objective is to control noise emission from those services. This appears rather uncoordinated.

With respect to sound isolating construction, the designer is allowed adopt construction options that are 'deemed-to-satisfy' the above performance requirements, or to choose an alternative construction providing it is verified that it meets defined test verification results, or may use 'another means' of verifying that the above will be achieved. Given that the performance requirements are long-term health and amenity outcomes it would not appear practical to consider the latter option.

As with the previous code issue a designer may use any of a number of 'deemed-to-comply' constructions based on a general construction description only. There is very little control of the design co-ordination requirements necessary to ensure the design is complete.

Sound Isolation Rating Units

A review of the many methods by which sound isolation qualities may be rated is outside the scope of this paper. However, the revisions to the BCA have adopted a fundamental change to previous requirements in giving emphasis to level-difference based verification units as well as adopting the spectrum adaptation terms that were originally proposed in ISO717 [1].

For the purpose of this discussion, design standards are considered to be equivalent using either R_w or STC ratings, although others may choose to argue the significance of the potential differences if they wish. The 1996 issue of BCA implemented a soft conversion from STC ratings to R_w ratings for all acoustic requirements and, while the Code did not state it, the regulatory authority had intended that the ratings applied to in-situ or field ratings. The units should therefore have been expressed as R'_w. By comparison, the new code proposes verification testing using $D_{nT,w}$, or normalised weighted-noise-level difference, and therefore applies to the composite overall building system and not to the individual elements. It is worth noting, however, that the 'deemed-to-comply' specifications do not include such rigour but refer to main elements only.

Historically, sound transmission loss related units, STC, R_w, R'_w etc, were preferred in building regulations as they represent a measure of energy difference across a building element and are independent of situation factors, such as common wall areas and room finishes. This had the disadvantage that approvals tended to focus on the performance of individual building elements and not on the overall integrity of the design. From a regulatory viewpoint, this was aggravated by the fact that a good design could be eroded by poor construction quality while still fundamentally complying with the Code. Under the new code, proof-testing is standardised through the incorporation of a reference reverberation time of 0.5 seconds in the receiving room, with the objective that this will improve consistency of testing by removing factors unique to each situation and that a future occupant may change.

Background to the New Ratings

The derivations of the units now included in BCA are internationally accepted procedures from ISO717. The background support to the adoption of the ratings, including the spectrum adaptation terms, was the introduction of the 2003 UK Building Regulations [2], although it is worth emphasising that the UK code gave only level difference based performance requirements and required pre-completion testing. In the UK regulations, generally similar technical standards to those given in Table 5 for wall and floor sound isolation ratings were adopted, however the requirements for services are fundamentally different. The UK regulatory change replaced the previous sound isolation performance requirements of $D_{nT,w}$ 53dB minimum wall sound isolation, $D_{nT,w}$ 52dB minimum floor sound isolation and a maximum impact noise level of $L'_{nT,w}$ 62dB. Thus, on the assumption that the new UK code equals or exceeds the stringency of the previous UK code, the adoption of the same technical standard by the revised BCA would appear to be an increase of the order of 7dB for airborne noise as well as a significant increase to control on impact noise. It also suggests that the 'deemed-to-comply' performance in the 2004 BCA is more lenient than is the verification proof-test requirement.

The UK Experience

The impact of the new UK Code on the UK construction industry has been significant. In particular the requirement for performance proof-testing for some classes of building was perceived by the industry to present a high level of commercial risk if projects were found to be non-complying, while at the same time testing added a potentially high testing cost. The outcome of this was representation to Government, through the House Builders Federation [3] seeking approval for an alternative compliance option based on the use of approved construction details, known as Robust Standard Details (RSDs). The introduction of these details could be construed to be similar to the BCA "deemed to comply" constructions, however an inspection of the RSDs shows them to be very significantly more developed and certified prior to their inclusion by a comprehensive field proof-test regime. A major research and development program was implemented through Napier University, Edinburgh, involving more than 600 wall and floor test structures. To qualify for inclusion in the RSD options, a construction detail had to achieve a proven field test performance of $50D_{nTw} + C_{tr}$ to prove that the use of the detail would justify elimination of the project-specific pre-completion test requirement of $45D_{nTw} + C_{tr}$. In place of the testing, use of robust standard details is supplemented by rigorous audit inspection records. This project culminated in an announcement to UK Parliament on 21 January 2004 that the alternative approvals basis allowing the use of the Robust Standard Details will be adopted. It is expected that this will come into force on 1 July 2004. While this has been a major step forward in the development of proven construction details, it is useful to ask whether this cost was warranted and, perhaps, where the need came from. Apart from the commercial risk of pre-completion test findings, the inclusion of spectrum adaptation terms would appear to be a factor influencing the industry reaction as testing had been widely required under the previous UK regulations. It is useful to observe that the UK construction industry measures these overall risks as at least equal to the cost penalty of 5dB due to the more stringent construction standard.

Spectrum Adaptation Terms

In regulating on the basis of weighted single number indices, such as R_w, it is implicit that the derivation of the unit is valid for the situation. That is, it is necessary that the relative importance of sound transmission loss at each one-third octave frequency band, implied by the R_w weighting alone is sufficient. The weaknesses in this assumption are that the weighting process, where low frequencies are deemed less important than high frequencies, includes errors, or that the noise spectra associated with the real sources occurring in the situations where the weighted single number index will be applied are not representative of those of the testing situation. That is, the R_w rating is derived from test data using pink noise, where energy in each frequency band is equally important, and the frequency weighting of the rating analysis therefore determines the relative importance of each band.

The 2004 BCA update has comprehensively adopted the use of spectrum adaptation terms proposed by ISO717. In the case of airborne noise, these adaptation terms define the difference between the standard weighted rating value (can be R_w, D_w etc) and the A-weighted attenuation achieved by the same construction when calculated for a pink noise source (i.e. adaptation term C) or a theoretical traffic noise source (C_{tr}). That is, if the R_w rating of a construction equals 30 and the attenuation of a pink noise source is 28dB(A) then the adaptation term C equals minus 2dB. For the case of a standard spectrum proposed by ISO717 for traffic noise situations, if the same construction achieves an attenuation of 26dB(A), the adaptation term C_{tr} equals minus 4dB.

The spectrum adaptation terms were introduced in the ISO methodology to replace the previous 8dB deficiency limitation rule. In the case of airborne noise transmission, the 2004 update of BCA adopts the use of the C_{tr} adaptation term for all situations, including noise generated by building occupants, water pipe noise and the like.

The appropriateness of the Ctr adaptation term has been examined for this paper, by investigating the typical spectra associated with relevant noise sources in two standardised situations. These are:

a) Rooms in which the background masking noise is a pink noise spectrum (i.e. equal sound pressure level at all octave bands) and
b) a second, more common situation, where the background masking noise spectrum is flat but descends with increasing frequency (i.e. at –3dB per octave).

That is, a computation was arranged to determine typical attenuation spectra required to achieve a signal-to-noise ratio of zero dB at each band for each source type and each of the two background masking conditions. The source spectra were gathered from the project noise survey records of Robert Fitzell Acoustics Pty Ltd and of Hyder Consulting Pty Ltd and represent real data from a range of public and entertainment spaces.

To obtain a consolidated set of spectra, the source raw data were analysed by fitting simple linear regression formulae of the form

$$Lp_{oct} = mX + b. \tag{1}$$

where X is the broad-band A-weighted level and Lp_{oct} is the unweighted octave band level in dB.

Table 1: Band and Disco Music regression parameters

	63	125	250	500	1000	2000	4000
m	0.93	0.98	1.02	1.08	1.25	1.16	1.14
b	10	2	-3	-12	-31	-27	-30

Table 2: People Noise regression parameters

	63	125	250	500	1000	2000	4000
m	0.42	0.59	0.82	0.95	1.08	1.11	0.99
b	37	24	10	2	-12	-18	-16

This data analysis produced a family of standardised source noise spectra representing typical spectrum shapes for each source type given an overall A-weighted level. Spectra were calculated for a range considered typical for each source type and compared with the two background noise spectra. This produced then two sets of spectra for each source, representing a desirable attenuation spectrum for each A-weighted value in each set, which could then be compared with the reference spectrum used to calculate C_{tr} given in Figure B.2 of ISO717.

Pink Noise Background Masking

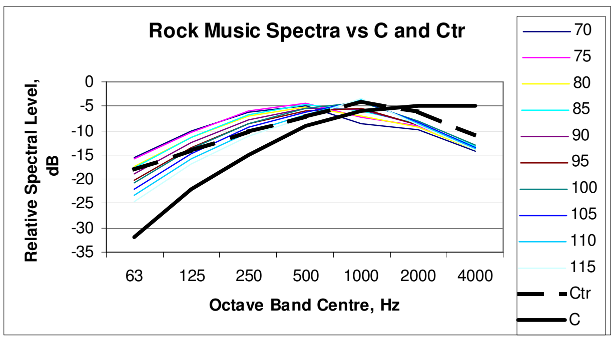

Figure 1. Attenuation vs frequency for music

Figure 1 shows that, for music, use of C_{tr} corresponds reasonably well with attenuation requirement for music at 100dB(A). Depending on the source level, potential error appears to be in the order of +/-4dB at any octave band.

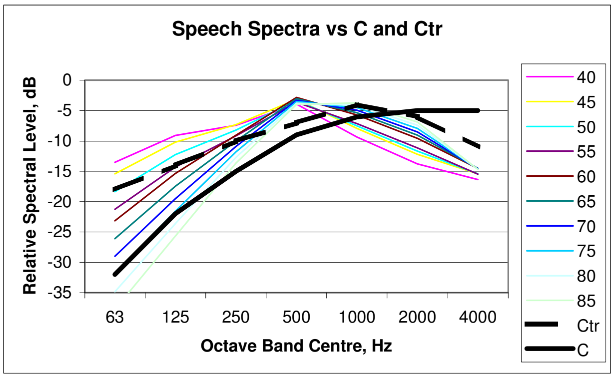

Figure 2. Attenuation vs frequency for speech.

Referring to figure 2 for speech, use of C_{tr} corresponds best with the spectrum content of speech at around 60dB(A) and lower but indicates errors of at least +/-5dB, and larger error at frequencies below 250Hz. For speech above 60dB(A) the use of C_{tr} grossly over-estimates the requirement at low frequencies.

-3dB per Octave Background Masking

For music, figure 3 shows use of C_{tr} over-estimates sound attenuation requirements at low frequencies by approximately 10dB. Spectrum adaptation based on use of C conforms reasonably well. Error appears in the order of +/-4dB.

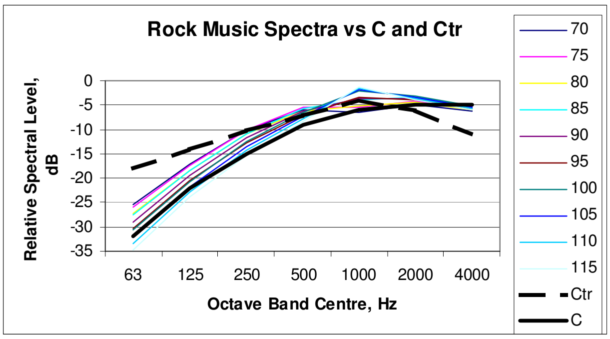

Figure 3. Attenuation vs frequency for music

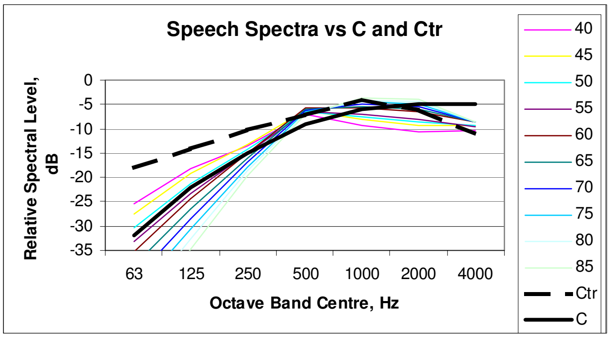

Figure 4. Attenuation vs frequency for speech

For speech, figure 4 shows the use of C_{tr} is inappropriate. Spectrum adaptation based on use of C conforms well for normal domestic levels with error +/-5dB

Services

Insufficient data was available to produce a similar review of the application of C_{tr} frequency adaptations to plumbing noise, however using a small number of field survey measurements of hydraulic services waste noise suggests that this may be reasonable for PVC waste pipes. It is likely to be invalid, however, for situations involving enclosure of water supply pipes, or when enclosing cast iron waste pipes.

D_{nTw}+C_{tr} and R_w Comparisons

Smith et al [4] have examined the effect on the existing acoustic standards required by the Scotland building regulations should the UK regulation standards be adopted in Scotland, and in particular the effect of the spectrum adaptation terms C_{tr} and C_i. The current Scotland requirements are generally similar to those from the previous UK regulation, being a target mean minimum airborne sound insulation rating of $D_{nT,w}$ 53dB for walls or 52dB for floors.

Smith used the Napier University Building Performance Centre database (i.e. the data used in compiling the Robust Standard Details) to evaluate whether constructions that were known to pass the existing Scotland building regulations would continue to pass under a new regulatory regime based on the UK Code. That is, his review examined whether systems known to pass a rating requirement of $D_{nT,w}$ 53dB would pass or fail under the rating requirement of $D_{nT,w}$ + C_{tr} of 45dB. Table 3 has been interpreted from the findings reported by Smith:

Table 3: $D_{nT,w}$ Requirements to Comply with 2004 BCA (derived from Smith et al)

Construction Type	Apparent $D_{nT,w}$ rating that equates with $D_{nT,w}$ + C_{tr} 45 dB
Masonry	$D_{nT,w}$ 51dB
Concrete	$D_{nT,w}$ 54dB
Framed walls (double stud)	$D_{nT,w}$ 54dB
Drywall or light timber floors	$D_{nT,w}$ 56dB

If the incorporation of spectrum adaptation terms (i.e. A-weighted attenuation for a traffic spectrum) for residential buildings is valid, Table 3 suggests that the use of $D_{nT,w}$ alone is clearly insufficient. On an assumption that the relationship between R_w and $D_{nT,w}$ will remain the same for each situation these findings suggest an error of the order of 5dB is inherent in the use of $D_{nT,w}$ alone. This error is lower than the apparent error shown above in the use of C_{tr}.

It is appropriate to observe that the adoption by BCA of level difference based units does increase the accountability of the builder to implement a co-ordinated design, though only if a test is undertaken.

Adaptation Terms for Floors

The spectrum adaptation term proposed by ISO717 is designated C_i and the 2004 issue of BCA has adopted the adapted rating units of $L_{nT,w}$ + C_i. After being included in the UK Code, the use of this spectrum adaptation term, Ci, was almost immediately discarded. This followed work such as that reported by Smith et al above and Rindel and Rasmussen [5] that showed that the incorporation of Ci was unreliable and, in the worst cases, allowed constructions previously known to be deficient to achieve compliance. The fact that BCA has included the impact adaptation term is a concern.

$D_{nT,w}$ vs R_w

Under previous Australian Building Regulation, compliance has been based on the achievement of a deemed to comply sound transmission loss for the party wall. If, under this arrangement, two adjacent apartments are fitted out with reverberant tile and glass finishes in one case and the other carpeted and curtained so as to be acoustically dead, each occupant would experience different noise reductions from their neighbour's activity noise. Proving that the completed apartment construction complied with the BCA obligations involved relatively complex testing and, as a result, was not widely undertaken. Uncertainty regarding the true transmission area connecting two apartments is the major source of error in this type of field test, although this may be reduced by the use of a calibrated sound power source, measurement by pseudo random noise source analysis, or sound intensity testing.

The new BCA imposes a weighted noise level difference measurement referenced to a standard reverberation time of 0.5 seconds. That is, the measured noise level difference between two apartments is adjusted at each one-third octave band by scaling the measured reverberation time in the receiving apartment against a standard value of 0.5 second. On face value, this testing sounds more simple to perform and likely to be better understood by the various stakeholders – builder, owner, certifier etc. However, testing under the new scenario will require accurate measurement of reverberation time in the low-frequency region, made more important by the inclusion of C_{tr}, in which there is a large potential measurement error due to the presence of insufficient room modes.

When T is 0.5 seconds and sound transmission occurs between two rooms only via a single common wall path, the $D_{nT,w}$ rating is approximately equal to the R_w rating of the common wall when the receiving side room is around 3 metres deep. The potential error in T rises exponentially as the room depth reduces.

The BCA allows a developer to choose between a deemed-to-satisfy construction, a system verified by endorsement of an expert, or a field based verification test to prove compliance if a construction different from those described in BCA is used. For the layman, the new process seems unlikely to be any more convincing than the previous regime.

Benchmarking

The BCA continues to be out of step with the norm for other national building codes in failing to regulate standards for external noise intrusion, and is only now requiring internal sound isolation standards that approach those of Austria, UK, Sweden and Germany though still not those of Austria, from a decade ago. (Tocci [6].

Home Unit Owner Priorities

In 2000 an apartment owner opinion survey was conducted in Sydney with the assistance of the Home Unit Owners Association. Three percent of recipients of a simple questionnaire responded and indicated the following priorities:

Table 4: Owner Occupier Preferences

Like to hear (top 5 in descending order)	Dislikes (most dislike in descending order)
Birds and natural sounds	Voices, talking, shouting from other apartments
Ocean noise	Impact noise and bangs caused by other occupants
Water, such as in a creek	Barking dogs
Wind noise in trees	Music from other apartments
Sporting activities near my home	Plumbing noise from other apartments

It is interesting to note that the survey respondent preferences clearly favour natural environmental sounds, while the strongest dislikes, with the exception of barking dogs, do relate to noise from other occupants. While the respondent opinions deemed music to be undesirable, the need to bias building design standards to those required for the isolation of music would not be warranted by the findings of this survey.

Conclusion

The use of C_{tr} does not appear to be warranted when consideration is given to the background masking noise spectrum present in residential buildings, however incorporation of the term C does appear more suitable and might warrant consideration.

Were the use of a spectrum adaptation term to be appropriate, the use of a complex term, D_{nTw}+C or D_{nTw}+Ctr, does not appear appropriate to a document intended for use by a large variety of stakeholders. Given that these units measure the A-weighted attenuation provided by building constructions under standard conditions, the use of a more simple unit would have been a major contribution to industry acceptance.

The incorporation of Ci for the assessment of impact noise has been deleted from comparable international codes and should not have been included.

After waiting for over 30 years to implement change, a seemingly hasty set of decisions has been taken. Why? One conclusion is that the management of building regulations in Australia is more preoccupied with the process than the content. There is no question the process of review has been too slow, with the result that City of Sydney and many other councils simply gave up and issued their own more stringent standards, most of which continue to include more comprehensive requirements than the BCA.

Is the terminology adopted for the new code requirements reasonable when these could have been expressed as an attenuation in dB(A) under standardised test condition? The reaction in the UK to difficult terminology and perceived risk shows that industry will accept a cost penalty to remove the confusion. At the end of the day, who will really pay this additional cost?

The BCA remains as an equivocal code where proof testing of the completed building remains unlikely and the deemed-to-comply details are not sufficient to ensure a complete design. It is questionable whether the development of Robust Standard Details in place of proof testing, as under the UK code, is a model to follow, as the outcome in the UK may yet be an inflexible book-of-rules where evidence of compliance is simply voluminous regulatory inspection records. An improved platform for understanding within the construction industry would be better.

References

[1] ISO 717-1, "Acoustics – Rating of sound insulation in building and of building elements – Part 1: Airborne sound insulation", 1996

[2] The Building Regulations 2000 – Approved Document E (Edition 2003) Office of the Deputy Prime Minister, HMSO 2003

[3] The House Builders Federation, "RSD Project Background", 2002

[4] Smith S., Mackenzie R., Mackenzie R. and Waters-Fuller T., "The implications of ISO717 spectrum adaptation terms for residential buildings", Acoustics Bulletin, Jan/Feb 2004

[5] Rindel J.H., and Rassmussen B., "Some consequences of including low frequencies in the evaluation of floor impact sound", ASA 132nd meeting – Hawaii, December 1996.

[6] Tocci, Gregory C., "Encyclopedia of Acoustics", ed Malcolm J. Crocker, ISBN 0-471-80465-7, Jon Wiley & Sons, 1997

Table 5: Comparison Summary - 1996 vs 2004 BCA

		1996 Code	2004 Code	
		Deemed-to-Satisfy (Field)	Deemed-to-Satisfy	Verification
Walls	Airborne Sound			
	Between dwellings	45 dB Rw	50dB Rw + Ctr	45dB DnT,w + Ctr
	Between a dwelling and a plant room, lift shaft, stairway corridor, hallway, etc.	45 dB Rw	50dB Rw	45dB DnT,w + Ctr
	Between habitable room in one dwelling and a laundry, kitchen, bathroom or toilet in another dwelling	50 dB Rw See below re impact properties	See below re impact properties	See below re impact properties
	Between a common service duct and habitable room	45 dB Rw	40dB Rw + Ctr	
	Between a common service duct and a bathroom, toilet, laundry or kitchen	30 dB Rw	25dB Rw + Ctr	
	Impact Sound			
	Between a habitable room in one dwelling and a bathroom, sanitary compartment, laundry or kitchen in another dwelling	generic - For other than masonry, construction must be two or more separate leaves; must provide equivalent impact performance to that of a double cavity brick wall	Generic - include discontinuous construction	generic – include discontinuous construction
Floors	Airborne noise			
	Between any two sole occupancy units	45 dB Rw	50dB Rw + Ctr	45dB DnT,w + Ctr
	Impact sound			
	Between habitable rooms in any two sole occupancy units	not mentioned	62dB Ln,w + Ci	62dB LnT,w + Ci
	Between habitable room and plant room, lift shaft, stairway corridor, hallway, etc.		62dB Ln,w + Ci	62dB LnT,w + Ci
Services	Airborne Noise			
	Construction separating a habitable room from a soil or waste pipe serving another dwelling	45 dB Rw	40dB Rw + Ctr	
	Construction separating a kitchen or non-habitable room from a soil or waste pipe serving another dwelling	30 dB Rw	25dB Rw + Ctr	
	Storm water pipes	Not mentioned	As above for soil or waste pipes	Not mentioned
	Ducts serving one dwelling which pass through or within a wall or floor cavity separating from another dwelling	Not mentioned	As above for soil or waste pipes	Not mentioned
	Water supply pipes serving one dwelling which pass through or within a wall or floor cavity separating from another dwelling	Not mentioned	Enclosure requirement as above for soil or waste pipes. If in a wall cavity the wall must be a double layer wall	Not mentioned
	Electrical outlets located in a wall separating dwellings	Not mentioned		Must be offset by given dimensions
	Pumps	Flexible coupling required		Flexible coupling required
Doors	Between a dwelling and a public stairway, public corridor etc	not mentioned	30dB Rw	25dB DnT,w
	Providing access to services	Must not open into any habitable room other than a kitchen		Must not open into any habitable room other than a kitchen