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MAR 2009

SOUND Insulation Properties of Concrete Walls and Floors

INTRODUCTION

The sound insulation performance of a wall or floor is a measure of its ability to reduce the amount of sound that is transmitted from one side to the other.

Concrete walls and floors provide the mass required to effectively reduce the transmission of sound, particularly low frequency sounds such as those from audio systems. Innovative composite systems, combining the performance of concrete with other materials, can economically achieve levels of sound insulation performance far exceeding the minimum required by the Building Code of Australia (BCA), enabling even the most stringent sound insulation requirements to be satisfied.

This data sheet outlines basic concepts relating to sound transmission and insulation, summarises the BCA's sound insulation requirements for walls and floors separating units and attached dwellings and lists some forms of concrete construction that satisfy the BCA's performance requirements. It also discusses how concrete systems provide a relatively simple and cost effective solution in terms of the required quality control necessary when constructing walls and floors.

SOUND TRANSMISSION

Sound sources

Two types of sound sources can produce the noise heard in an adjacent unit or dwelling: *airborne* such as speech, musical instruments and loudspeakers (stereos, radios, TVs and home theatre systems) and *impact* such as footsteps, furniture moving and some appliances.

Airborne sounds

Airborne sounds consist of successive pressure waves or vibrations which are generated from a source such as speech or loudspeakers, and carried (or transmitted) through the air. They can not travel through walls or floors, but set up vibrations in them. The vibration of these elements causes the air on the other side to vibrate; it is these new airborne vibrations that transmit the sound.

CONCRETE walls and floors provide the mass required to effectively reduce the transmission of sound

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The greater the mass of the wall or floor, the more difficult it is to set up vibrations in it, and hence more difficult to transfer sound from one side to the other. Concrete walls and floors perform well in reducing the transmission of airborne sounds due to their mass.

Other factors, such as the fixity at the edges of the walls and floors also affect the ease with which vibrations can be set up in the element and the natural frequency at which the element will vibrate. Concrete walls and floors generally incorporate good fixity at connections to further improve the ability to reduce the transmission of sound.

Impact sounds

Impact sounds are caused by objects striking the wall or floor. Examples include footsteps, objects dropped on floors, movement of chairs and possibly some appliances. The vibrations set up in the wall or floor from impact tend to spread out over the entire element plus other elements connected to it. These vibrations result in vibrations in the adjacent air (airborne sound) or vibrations in objects attached to, or resting on, the wall or floor.

Direct and indirect transmission of sound

Sound energy can be transmitted from one side of a wall or floor to the other either directly or indirectly. Direct transmission is where the wall or floor element itself transmits the sound from one side to the other. Indirect (or flanking) transmission is where the path of the sound energy is via another element attached to the wall or floor, or some other pathway.

Often, separating walls may perform adequately in reducing the transmission of sound, but noise levels in the adjoining occupancy may still be 'unacceptable' due to other building elements or design features allowing a higher level of sound transmission. For example, sound transmitted over the top of a wall through some form of air gap, say in the ceiling or roof space, or perhaps via closely-spaced windows/doors on external walls.

Because sound typically travels between occupancies by a combination of both direct and indirect transmission, it is equally important both to provide a wall or floor element having the required sound insulation performance and to consider design aspects and provision of appropriate wall/floor/ceiling combinations and connection details.

Concrete walls and floors have traditionally provided both the mass and simple connection details to limit both the direct and indirect transmission of noise.

SOUND INSULATION

Weighted sound reduction index (R_w)

The weighted sound reduction index, R_w, is a single number value expressed in decibels (dB) which describes the overall sound insulation performance or sound reduction that the wall or floor provides. Note that sound pressure levels are usually expressed in decibels, with one decibel being the smallest change in sound pressure level or intensity (loudness) detectable by the human ear.

R_w ratings are determined by laboratory testing. A sample of the wall or floor is constructed in an opening separating a source room (where sounds are generated at various frequencies) from a receiver room, where the sound level is measured. The difference in sound level between the source room and receiver room represents the sound reduction or transmission loss, R, through the test specimen for that frequency, in decibels (dB). Measurements are conducted in one-third octave bands over frequencies typically from 100 to 3,150 Hz.

To determine the R_w value, the results for each frequency are plotted on a diagram (**Figure 1**) and a reference curve (from AS/NZS ISO 717.1[1]) is positioned so that the sum of the differences at each test frequency under the reference curve is as large as possible but not more than 32 dB. Once the reference curve is correctly positioned, the sound reduction at 500 Hz is determined and this becomes the single-number R_w value. The procedure results in the sound reduction index being weighted to about the average sound reduction in the middle of the human hearing range, with higher values indicating better performance.

Weighted sound reduction index plus spectrum adaptation term ($R_w + C_{tr}$)

The spectrum adaptation term, C_{tr}, takes into account the performance of the building element in specifically reducing the transmission of low frequency sound. The term is calculated by combining the measured performance of the wall or floor element at various frequencies (**Figure 1**) with a curve (**Figure 2**) that represents a typical low frequency sound source (typically traffic noise and hence the 'tr' subscript). As most noise related issues involve the transmission of low frequency sounds from audio equipment, the BCA's sound insulation requirements generally include the C_{tr} term by setting a minimum $R_w + C_{tr}$ value – typically 50 dB.

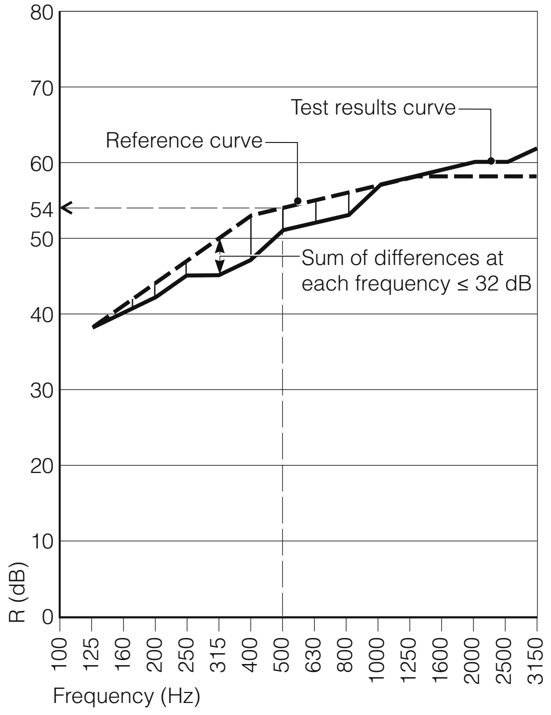


Figure 1: Determination of R_w for 150-mm-thick concrete wall

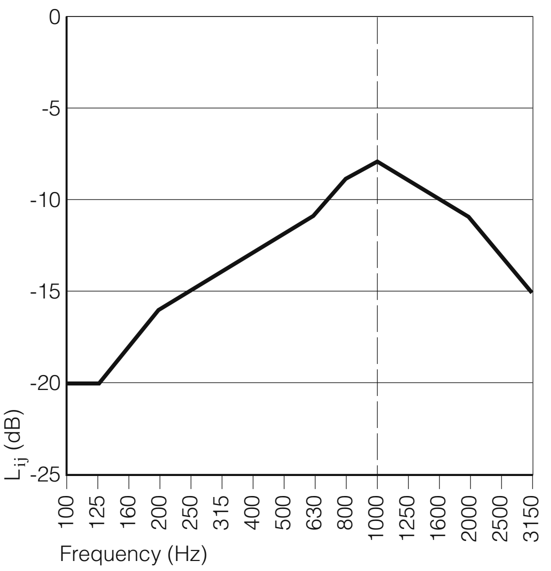


Figure 2: Sound level spectra to calculate the spectrum adaptation term C_{tr} (from AS/NZS ISO 717.1[1])

Weighted normalised impact sound pressure level with spectrum adaptation term ($L_{n,w}$ + C_I)

Similar to R_w, $L_{n,w}$ is a single number value which describes the overall impact performance or sound insulating rating of the building assembly (usually a floor) when subject to impact sounds. L_n values are measured in a laboratory by placing a standard tapping machine on a test assembly and measuring the impact transmission through the assembly in one-third octave bands using a receiver located directly below. The data is adjusted (or normalised – subscript 'n') to a standard receiving room absorption of 10 m^2 to account for the influence a receiving room has on sound pressure levels.

To determine the single number $L_{n,w}$ value, a weighting procedure similar to that for R_w is used. The results for each frequency are plotted on a diagram and a reference curve (from AS/NZS ISO 717.2[2]) is positioned so that the sum of the differences at each test frequency under the reference curve is as large as possible but not more than 32 dB. Once the reference curve is correctly positioned, the impact sound pressure level at 500 Hz is determined and this becomes the single-number $L_{n,w}$ value.

C_I (subscript 'I' for impact) is a spectrum adaptation term that adjusts the single $L_{n,w}$ value to account for typical footstep noise.

Unlike R_w + C_{tr} where higher values indicate improved performance, lower $L_{n,w}$ + C_I values (ie the sound pressure level is lower) are desirable. The BCA places an upper limit of 62 dB on the impact performance of floors.

AMBIENT SOUND LEVELS

Typically, there will always be some ambient or background sound, eg from traffic, air conditioners, fans, refrigerators. AS/NZS 2107[3] contains recommended ambient sound levels for different areas of occupancy in buildings in order to provide a comfortable environment to work, live or sleep **Table 1**. Note that the BCA's sound insulation requirements are not intended to eliminate all sound transmission, but to generally reduce it to an acceptable level.

The 'A' weighted decibel (dB(A)) sound levels given in **Table 1** are measured by a meter having an electrical circuit that adjusts the sound pressure scale so that the meter has the same sensitivity to sound at different frequencies as the average human ear. It is a means of correlating objective laboratory measurements, with people's subjective assessments of sound at different frequencies. Because dB (A) values take into account people's attitudes towards the nuisance value of sounds, they are generally used for setting limits on ambient sound levels.

The subjectivity of the nuisance value of sounds can be seen in **Table 1**, people living near major roads, who may become accustomed to road noise, can be expected to find higher maximum sound levels acceptable than would people living near minor roads.

Referring to **Table 2**, examples of a sound pressure level of 30 dB (recommended level for sleeping areas from **Table 1**) include a soft radio and quiet conversation.

Table 1 Recommended design sound levels in residential buildings *(extract from Table 1 in AS 2107)*

Type of occupancy/activity	Recommended design sound level, L_{Aeq}* dB(A) Satisfactory	Maximum
Houses and apartments near minor roads		
Living areas	30	40
Sleeping areas	30	35
Work areas	35	40
Houses and apartments near major roads		
Living areas	35	45
Sleeping areas	30	40
Work areas	35	45

* L_{Aeq} *is the equivalent continuous A-weighted sound pressure level*

Table 2 Typical sound pressure levels from various sources

Sound pressure level (dB)	**Description**	**Examples**
0	Threshold of hearing	Acoustical test room
10	Very faint	Normal breathing
20	Quiet	Whisper at 1 m Quiet room
30		Average home Soft radio Quiet conversation
40	Normal	Quiet radio/office Motor car
50	Noisy	Average conversation
60		Average radio/office
70	Loud	Busy street Argument
80		Noisy office Vacuum cleaner Door slamming
90	Very loud	Printing plant Inside city bus
100		Loud car horn at 6 m Wood saw at 1 m

ACCEPTABLE SOUND INSULATION PERFORMANCE

Where walls and floors separate sole-occupancy units, their acoustic performance should ensure that sound from one dwelling does not result in ambient sound levels in the adjoining dwelling that exceed the values regarded as providing a satisfactory working, living or sleeping environment.

The R_w or $R_w + C_{tr}$ value is the amount by which the building element will reduce the sound pressure level from one side of the element to the other. For example, the minimum requirement set in the BCA for a wall or floor separating sole occupancy units ($R_w + C_{tr} \geq 50$ dB) will reduce the sound from a vacuum cleaner or door slamming (80 dB) to 30 dB or the level regarded as an acceptable ambient sound level for sleeping areas. Average conversation, TV and radio sounds will be reduced to even lower levels **Table 2**.

Note that in most situations, some sound will still be transmitted, but at levels well below what is regarded as an acceptable ambient sound level. Also, because of the subjectivity of noise, some residents may accept a certain level of noise from outside sources such as motor cars, while they may consider any noise from an adjoining dwelling, even below the recommended ambient levels, as obtrusive and unacceptable.

SOUND INSULATION REQUIREMENTS IN THE BCA

The BCA gives minimum sound insulation performance requirements for the walls that separate attached Class 1 buildings and for the walls and floors that separate sole-occupancy units in Class 2 and 3 buildings and Class 9c aged-care buildings to allow the occupants to sleep, rest and engage in normal domestic activities in satisfactory conditions (ie ambient sound levels below those in **Table 1**). General descriptions of building classes are:

- Class 1a – a single dwelling being either a detached house or group of attached dwellings separated by fire-resisting walls.
- Class 1b – a boarding house, guest house, hostel or the like for no more than 12 people, with a total floor area not exceeding 300 m^2 and not located above or below another dwelling or Class of building other than a private garage.
- Class 2 – a building containing two or more sole-occupancy units each being a separate dwelling.
- Class 3 – a residential building other than Class 1 or 2 used as a place of long-term or transient living for a number of unrelated persons, eg residential part of a hotel, motel, school, health-care building or detention centre.
- Class 9c – an aged-care building.

To ensure the comfort and well-being of occupants with respect to sound, the BCA requires the sound insulation performance and/or type of construction listed in **Table 3**. The simplest method of complying with these performance requirements is to adopt one of the acceptable forms of construction for walls or floors shown in **Appendix A**.

If alternative forms of construction are considered, the building element should be tested in a laboratory to confirm that the performance requirements will be satisfied. For Class 2, 3 and 9c buildings the BCA gives the option of verifying the airborne and impact performance of the wall or floor on site. This is known as the verification method of compliance and the BCA references the procedures to be used to determine the airborne and impact performance of both walls and floors and the performance requirements to be achieved. If testing on site, the effect of indirect transmission should be considered, as this may prevent an accurate measurement of the actual performance of the wall or floor element in question.

Other requirements in the BCA include:

- Walls requiring discontinuous construction for impact **Table 3** are to consist of two leaves separated by a minimum 20-mm cavity. Apart from at the edges, the only linkage allowed across the cavity are the wall ties required for cavity masonry construction, and these must be of the resilient type.
- Joints between concrete slabs or panels and masonry walls and any adjoining construction are to be filled solid.
- Specific sound reduction requirements where services are located within separating walls.

ACHIEVING SOUND INSULATION PERFORMANCE

Inadequate sound insulation performance often results from design and construction quality issues (rather than an incorrectly selected form of construction) and from unrealistic expectations of how much noise from adjacent dwellings/units should be audible. Also, if the sound is louder than 'normal', even though the building elements may comply with the BCA's requirements, noise levels in adjacent dwellings will be higher, possibly above the satisfactory ambient levels stated in AS/NZS 2107 **Table 1**.

Design issues involve items such as closely spaced windows and doors on external facades and poorly detailed joints, plus roof and ceiling spaces that allow indirect transmission of sound. Construction quality issues can vary depending on the type of wall or floor and the materials used. Concrete walls and floors are generally less reliant on workmanship issues and have only a limited number of quality issues that need to

Table 3 BCA sound insulation requirements for walls and floors

Sound	Classification of building	Element and location	Requirement
Airborne	Class 1	Separating wall between attached dwellings	$R_w + C_{tr} \geq 50$ dB
		Separating wall (containing a duct, soil, waste, water supply pipe or storm water pipe) adjacent to a habitable room other than a kitchen	$R_w + C_{tr} \geq 40$ dB
		Separating wall (containing a duct, soil, waste, water supply pipe or storm water pipe) adjacent to a kitchen or non-habitable room	$R_w + C_{tr} \geq 25$ dB
	Class 2 and 3	Wall or floor separating sole-occupancy units	$R_w + C_{tr} \geq 50$ dB
		Wall separating a sole-occupancy unit from a plant room, lift shaft, stairway, public corridor, public lobby or the like, or parts of a different classification	$R_w \geq 50$ dB
		Floor separating a sole-occupancy unit from a plant room, lift shaft, stairway, public corridor, public lobby or the like, or parts of a different classification	$R_w + C_{tr} \geq 50$ dB
		Door assembly between a sole-occupancy unit and stairway, public corridor, public lobby or similar	$R_w \geq 30$ dB
	Class 9c	Wall or floor separating sole-occupancy units	$R_w \geq 45$ dB
		Wall separating sole-occupancy unit from a kitchen, bathroom, sanitary compartment (except for ensuite), laundry, plant room or utilities room	$R_w \geq 45$ dB
Impact	Class 1	Wall separating a habitable room (other than a kitchen) in one dwelling from a bathroom, sanitary compartment, laundry or kitchen in an adjoining dwelling	Discontinuous construction
	Class 2 and 3	Walls separating a bathroom, sanitary compartment, laundry or kitchen in one sole-occupancy unit from a habitable room (other than a kitchen) in an adjoining unit	Discontinuous construction
		Wall separating a sole-occupancy unit from a plant room or lift shaft	Discontinuous construction
		Floors separating sole-occupancy units, or a sole-occupancy unit from a plant room, lift shaft, stairway, public corridor, public lobby or the like, or parts of a different classification	$L_{n,w} + C_I \leq 62$ dB
	Class 9c	Walls separating a sole-occupancy units from a kitchen or laundry	For other than masonry, be two or more separate leaves without rigid mechanical connection except at the periphery OR Impact resistance to be not less than that for walls in Appendix A having $R_w \geq 45$ dB

be addressed to ensure that the required sound insulation performance of the as-built wall or floor is achieved.

Concrete wall panels of appropriate thickness and with any gaps around the edges or between panels adequately grouted or sealed with an acoustic rated sealant will generally give the required performance.

For concrete masonry wall construction, the important issues are ensuring that the density of the masonry units used is the same as those tested, and that all joints are filled during laying, including those at the edges of the wall. Solid masonry units with frogs should be laid frog up so that all bed joints can be filled. This will ensure that the mass is achieved and air paths within the wall are avoided. Sound insulating sealants also provide an effective way to seal gaps at the top and ends of the wall.

Precast floor elements are typically produced in steel moulds meeting strict tolerance requirements. The manufacturer's recommendations for installation, topping thickness, joints and ceiling details should be followed to ensure that appropriate sound insulation performance is achieved.[4]

When lightweight materials are used in conjunction with concrete in composite walls and floors the effective jointing of materials (including the insulation) is necessary to eliminate gaps that sound can pass through or 'penetrate'. Even small gaps such as unfilled joints can be enough to significantly affect the overall performance.

SUMMARY

There is a variety of forms of concrete construction that easily and cost effectively achieve the BCA's minimum sound insulation performance requirements (see **Appendix A**). If higher sound insulation ratings are required, various composite-walling systems utilising a concrete-based core element can be used.

The mass contained in most concrete walls and floors provides an excellent barrier to the transmission of airborne sounds and is particularly effective in reducing the transmission of low frequency sounds generated by common sources such as televisions, stereos and, increasingly, home theatre systems.

Concrete provides good impact sound insulation, with a 150 mm-thick floor/wall easily satisfying the BCA's requirements. Also, various lining board systems can provide discontinuous wall construction (see **Table 3**). If attached dwellings or units should be designed to avoid the need for discontinuous construction, eg by bathrooms and kitchens not being located adjacent to habitable rooms in adjacent units, the economy of using concrete options will improve even further.

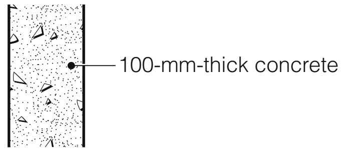
REFERENCES

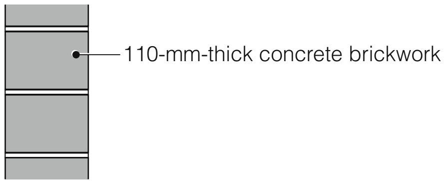
1 AS/NZS ISO 717.1 *Acoustics – Rating of sound insulation in buildings and of building elements Part 1: Airborne sound insulation*, 2004
2 AS ISO 717.2 *Acoustics – Rating of sound insulation in buildings and of building elements Part2: Impact sound insulation*, 2004
3 AS/NZS 2107 *Acoustics – Recommended design sound levels and reverberation times for building interiors*, 2000
4 *Precast Concrete Handbook* National Precast Concrete Association Australia, 2002

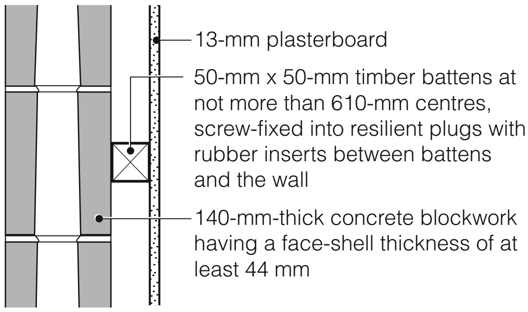
APPENDIX A ACCEPTABLE FORMS OF CONCRETE CONSTRUCTION

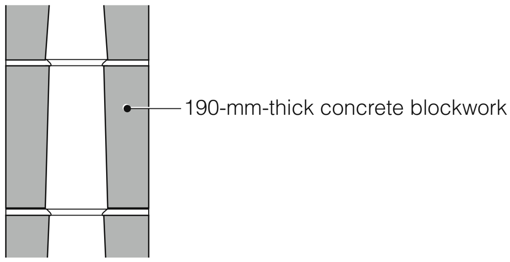
The forms of construction listed in this Appendix represent the minimum requirement. Increased thickness will improve sound insulation performance.

Walls having $R_w \geq 45$ dB



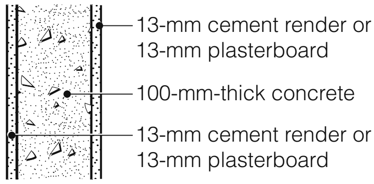


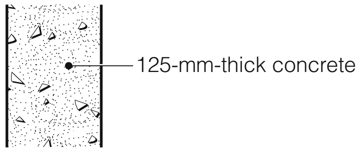


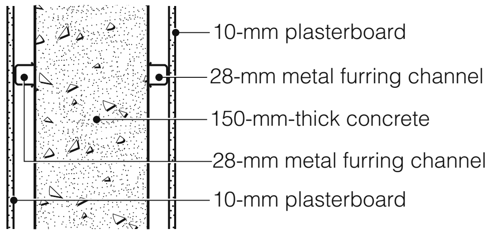


Walls having $R_w \geq 50$ dB

In addition to the walls below providing $R_w + C_{tr} \geq 50$ dB







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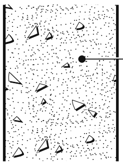
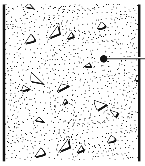
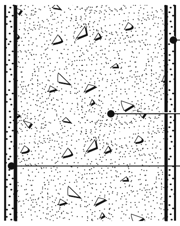
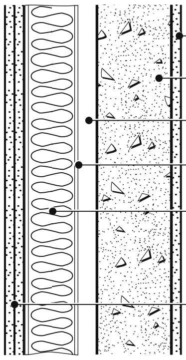
APPENDIX A ACCEPTABLE FORMS OF CONCRETE CONSTRUCTION *(continued)*

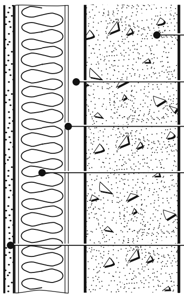
Walls having $R_w + C_{tr} \geq 50$ dB





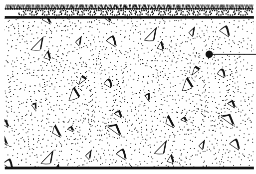


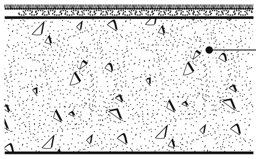


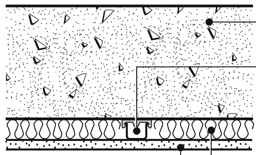


Floors satisfying airborne and impact sound requirements

($R_w \geq 50$ dB, $R_w + C_{tr} \geq 50$ dB and $L_{n,w} + C_I \leq 62$ dB)

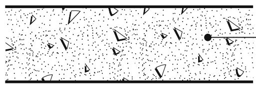






Floors satisfying airborne sound requirements

($R_w \geq 45$ dB)



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