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Association of Australasian Acoustical Consultants
Guideline for Educational Facilities Acoustics

Version 1.0

Association of Australasian Acoustical Consultants

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1.0 INTRODUCTION

Members of the Association of Australasian Acoustical Consultants (AAAC) have been concerned for some time that there are no Australia-wide regulations or standards that encompass all aspects of the acoustical qualities of educational and training facilities, including primary and secondary schools.

Students who cannot hear clearly in a classroom tend to lose concentration and eventually they are not part of the proceedings. Valuable teaching time is lost and student progress is impaired. Overseas studies have shown that students are at a disadvantage where the appropriate acoustic environment is not present.

The importance of this situation has resulted in the development of acoustic criteria for educational facilities in the UK, the USA, New Zealand and Sweden.

Whilst the Building Code of Australia (BCA) details minimum standards for buildings, it does not provide specific recommendations for educational facilities. The development of acoustical standards in education facilities has been left to each individual State, and in past years the (former) Public or Works Departments have produced their own guidelines and criteria. However, with the current reorganisation of government departments, many of these guidelines have fallen into neglect and disuse, and making reference to acoustic terminology which has been superseded by updated Australian Standards.

The recommendations in this document are provided with the objective of improving the acoustic environment in educational facilities with particular emphasis on classroom acoustics, which is now regarded internationally as one of the prime considerations in the design of new classroom facilities.

SCOPE

The intent of this guideline is to present the views of the AAAC and its members in regard to the design of educational facilities. It deals with the major distraction issues, including the intrusion of external noise, noise generated by building services and noise transferred between individual spaces, impact noise and reverberation time for good speech intelligibility.

This guideline is not intended to compete with established statutory or advisory codes such as the BCA, and as stated, is consistent with the requirements of BCA standards. It is intended to be complementary to, but more comprehensive than, local authority building requirements and individual and state guidelines, where they exist.

This document is based on overseas experience and standards, together with the current experience and opinions of AAAC members. It will be reviewed periodically in order to reflect changing community expectations, educational objectives and new requirements. As a guideline, it is subject to change, and it is recommended that users check with an AAAC member to confirm that the most recent release of this guide is being used. Current copies of the guideline are available from the AAAC website (www.aaac.org.au); details of the members to contact are provided on the website.

Outdoor teaching and learning activities are often likely to occur at educational facilities. This issue is outside the scope of this document; however, some guidelines will be given to provide assistance.

2.0 BACKGROUND

Much of what is learnt in school is through extended periods of hearing and listening. For example, school children spend an average of four to five hours per day in classrooms.

Excessively noisy or reverberant rooms can make the hearing and understanding of speech very difficult and are inappropriate for education. Children, owing to their neurological immaturity and lack of experience in predicting a message from context, are inefficient listeners. They require optimal conditions in order to hear and understand[1]. Those who continually miss key words, phrases and concepts in class are significantly disadvantaged.

As a result of dramatic changes in teaching style, the traditional lecture style of class has been replaced so that, depending on the class level, about 40% of time in class is spent in group work and for primary students about 30% in mat work. More than 70% of teachers in class act dynamically, walking around talking to students from numerous positions within the room. This has changed the way information is delivered to, and received by, students.

New classrooms and school facilities must be designed to accommodate these changes in teaching and the need to provide the best possible conditions for learning.

The results of social surveys[2] have shown a clear correlation between noise levels and performance in schools. The need for an appropriate set of consistent Australia-wide acoustical criteria has arisen. Students, in particular young children, require good listening conditions. This is known as having a high signal-to-noise ratio. The teacher's voice needs to be loud and clear above the (unoccupied) background noise environment which may include traffic, other school related activities; eg, on sports fields and in corridors, or even air-conditioning noise.

The clear-communication requirement is particularly important for those students with hearing impairment or those from non-English speaking backgrounds, two groups who can make up 25-30% of students in primary school classes[3].

This guideline considers not only the activities that occur inside classrooms and teaching spaces, but also those activities which occur in adjacent spaces and outside during the course of a day. The ideal classroom should be acoustically "friendly", not just when the student has normal hearing and is sitting quietly and close to the teacher. The room should also be friendly for the hearing impaired student or student with learning difficulties and when there is high activity noise levels arising from group discussions. Acoustical considerations must not restrict teaching styles, but should complement the wide variety of teaching methods used by teachers, as well as the ability and the age of the students. Further, teachers in class should be able to use a natural teaching voice, free from vocal stress to minimise long term strain and even damage.

For the specific case of students in classrooms, the following acoustical design conditions should be satisfied:

- A spoken voice level at least 15dB above the background noise level throughout the room;
- Background noise levels of 30-40 dBA, or less when unoccupied;
- Overall sound levels (consisting of teaching voice and student voice) no greater than 65-70 dBA throughout the room;
- Sound absorbing materials, placed to minimise reverberation to less than 0.4s in primary teaching spaces and 0.6s in secondary teaching spaces, including at least 40% absorptive treatment on the ceiling;
- A Speech Transmission Index STI > 0.6 in open plan teaching and study spaces.

For the further case of students with special hearing requirements, the following acoustical design conditions should also be satisfied:

- Reverberation time of 0.4 seconds or less;
- Signal to noise ratio of greater than 20dB.

These are discussed in detail below.

The AAAC has put together this document, drawing on work from the Building Research Association of New Zealand (BRANZ, New Zealand[4,5]), ANSI (United States of America)[3] and the Department for Education and Skills (DFES) document Building Bulletin 93 (BB93, United Kingdom)[6] as well as joint Australia/New Zealand Standard AS/NZS 2107:2000 *Acoustics – Recommended design sound levels and reverberation times for building interiors*[7] for consideration and use by professionals, architects, builders and school administrators.

3.0 OBJECTIVES

The objectives of this guideline are as follows:

- To provide a consistent Australia-wide approach for the design of appropriate quality standards for acoustics in educational facilities;
- To ensure that sound levels within occupied spaces of educational facilities are such that appropriate discussion, communication, education and comprehension can occur;
- To prevent students suffering from adverse acoustic conditions within their educational environment.

ACOUSTICAL DESIGN CONDITIONS

The AAAC believes that learning spaces in educational facilities require substantially more favourable conditions than are currently provided in many Australian schools. The AAAC recommends that the following qualities should be achieved in teaching spaces and associated areas in educational facilities:

- Appropriate background noise levels;
- Reverberation times appropriate to the room use and function;
- Good signal-to-noise ratios (S/N);
- Good speech intelligibility (in open plan areas);
- Minimum disturbance or distraction from nearby or adjacent activities, or external noise sources.

With acoustical design, it is important to achieve a balance of performance across all these design attributes.

PROPER DESIGN OF EDUCATIONAL FACILITIES FOR ACOUSTICS

The design of educational facilities should consider the following aspects that determine the acoustic environment in learning spaces. A more detail description of acoustic terms is set out in Section 6.0.

Internal Ambient Noise Levels

Internal ambient noise levels are generally determined by two different noise sources: noise from building services and external noise:

- Building services noise involves noise from ventilation and air-conditioning services and any other equipment associated with the operation of the facility such as plumbing services;

- External noise intrusion is most commonly caused by transportation systems such as road, rail and air traffic. It may also include plant noise from nearby industry, commerce and residential buildings. Other school activities such as sport my generate noise intrusion.

Achieving suitable internal noise levels in educational facilities is likely to require assessment of noise levels from building services equipment. Noise control or attenuation of this equipment should be considered at the design stage. Also, an assessment of noise levels from external noise sources should be conducted, with the building envelope being constructed of materials which reduce, to defined limits, the ingress of external noise, and internal walls/ceilings constructed to separate school room functions and activities.

Internal ambient noise levels are measured using the assessment methodology of the AS 2107-2000.

Floor Impact Isolation

Floor impact noise can arise from walking, chair-scraping and other activities on a hard floor surface in one room transmitting into rooms adjacent and beneath. Control of floor impact noise is required into noise-sensitive areas such as classrooms.

Internal Sound Insulation

In general terms it is the sound level difference or transmission loss between the two rooms or from outside to inside, which is also adjusted to simulate a typical furnished room. The measure is set out in Section 6.0.

Reverberation Time

Room acoustics within a space are commonly described by the Reverberation Time, T_{60}, which is measured in seconds and is an indication of how quickly sound decays within a space.

The higher the T_{60}, the more reverberant or acoustically "live" is the space. A low T_{60} indicates a quiet or acoustically "dead" space. A higher T_{60} generally promotes higher activity noise levels which results in worsening conditions for communication.

Speech Transmission Index

Speech Transmission Index (STI) describes the clarity of speech in a space taking account of the space's acoustic characteristics and the background noise level and other noisy activities which may be occurring.

In typical classrooms and learning spaces, of less than 400m^3 volume, good speech clarity can be achieved by designing to the reverberation time and noise criteria given, using ceiling and/or wall treatments to achieve required levels of acoustic absorption. For more complicated spaces such as open plan teaching areas, atria and gymnasiums, good speech clarity is not so readily achieved and an STI assessment with compliance measurements should be carried out for each case. Note that for many spaces the acoustic consultant would need to make assumptions about the noise levels in occupied rooms for STI predictions.

At present, STI is considered the most robust and practicable assessment tool for use in schools.

Discussion of Design Factors

It is important that all acoustical design factors be considered in the design and construction of educational facilities.

For example, research[1] suggests that reverberation times of 0.4s or less in small and mid-sized classrooms, and 0.6s or less in larger classrooms, will not degrade speech intelligibility excessively as long as speech level greater than background noise (signal-to-noise ratios) of 10-15dB or better are maintained. For a typical speaker in a classroom, the requirement for good understanding will be satisfied when the background noise is sufficiently low, that is around 35 dBA.

Thus, the acoustical performance criteria for internal ambient noise presented in Table 1, which includes external noise intrusion and sound insulation to adjacent spaces and reverberation time, must be satisfied to achieve a suitable learning environment in the classroom.

4.0 ACOUSTICAL DESIGN CRITERIA

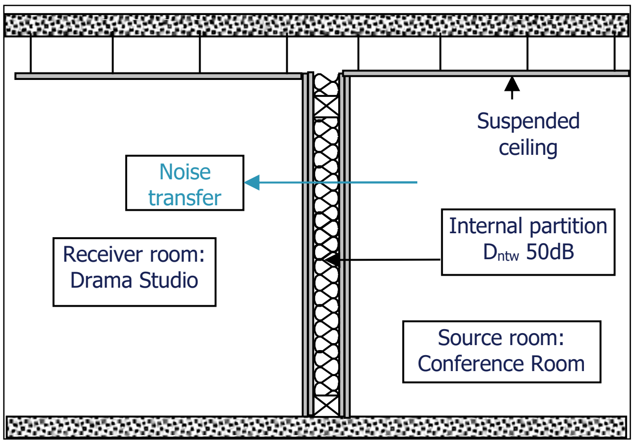
The recommended acoustic design criteria for main learning and auxiliary spaces in educational facilities is provided in Tables 1, 2, 3 and 4 in this document.

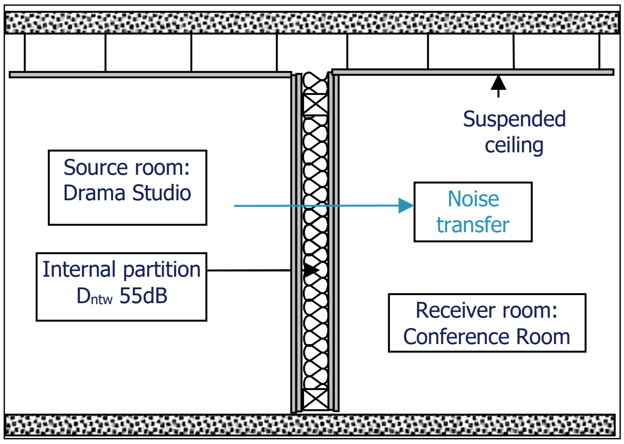
Internal ambient noise level and reverberation time criteria are provided in Table 1.

Sound insulation criteria are provided in Tables 2 and 3. Airborne sound insulation ratings depend on the sensitivity to noise of the receiving space and the noise activity generated in the adjacent, source space.

Example (see Appendix for detail of technical terms):

Consider a partition between a Drama studio and a Conference Room. If we consider noise transmission from the Conference Room to the Drama Studio, it can be seen from Table 2 that Conference Rooms have average activity noise and Drama Studios have very low noise tolerance. Thus from Table 3 a partition rating of $D_{nT,w}$ 50 is required. If we consider noise transmission in the other direction, from the Drama Studio to the Conference Room, it can be seen from Table 2 that Drama studios have high activity noise and Conference Rooms have low noise tolerance. Thus from Table 3 a partition rating of $D_{nT,w}$ 55 is required. The larger $D_{nT,w}$ value is selected as the criteria for the separating partition. Thus in this example, the partition should achieve a performance rating of $D_{nT,w}$ 55.





Floor impact insulation ratings are also provided in Table 2. For example, a Drama studio should have an $L_{nT,w}$ 55 rating meaning that impact noise generated in overhead or adjacent spaces should not exceed $L_{nT,w}$ 55 in the Studio, when measured in accordance with appropriate Australian Standards.

An STI criterion for open plan spaces in provided in Table 4.

Table 1 – Recommended internal noise levels and reverberations times

Room	Upper limit for the internal ambient noise level, L_{Aeq} (dB)	Reverberation time Maximum time, (s) T_{60}
Art/craft studios	40	<0.8
Assembly halls up to 250 seats	35	see Note 2
Assembly halls over 250 seats	35	see Note 2
Audio-visual areas	35	<0.8
Computer rooms – Teaching	40	<0.6
Computer rooms – Laboratories	45	<0.6
Conference room	35	0.6-0.7
Corridors and lobbies	45	0.6-0.8
Dance Studios	40	<1.2
Dining rooms	45	<1
Drama Studios	30	<1
Duplicating rooms/stores	50	-
Engineering workshops	50	see Note 2
Gymnasiums	40	<1.5
Interview/counselling rooms	35	<0.6
Kitchens	50	
Laboratories – Teaching	40	<0.7
Laboratories – Working	45	<0.8
Lecture rooms – up to 50 seats	35	see Note 2
Lecture theatres – without speech reinforcement and >50 seats	30	see Note 2
Lecture theatres – with speech reinforcement	35	see Note 2
Libraries – General areas	40	<0.6
Libraries – Reading areas	35	<0.6
Libraries – Stack areas	45	<0.6
Manual arts workshops	40	see Note 1
Medical rooms (First aid)	40	<0.8
Music practice rooms	35	see Note 2
Music studios	30	see Note 2
Office areas	40	<0.8
Open plan teaching areas	40	<0.8
Professional and administrative offices	35	<0.8
Teaching spaces – Primary schools	35	0.4-0.5 see Note 2
Teaching spaces – Secondary schools	35	0.5-0.6 see Note 2
Staff common rooms	40	<0.6
Study Rooms	35	<0.8
Toilet/change/showers	50	-
Other		
Teaching spaces – Hearing impaired	30	<0.4

Room	Upper limit for the internal ambient noise level, L_{Aeq} (dB)	Reverberation time Maximum time, (s) T_{60}
Swimming pools	50	<2
Nursery school - Play rooms	35	<0.6
Nursery school - Quiet rooms	35	<0.6

Notes: 1. Refer to AS 2107 for further details.
2. The appropriate reverberation time shall be influenced by the use, volume and geometry of the space. Guidance from an acoustical engineer should be sought.

Note that rain noise is excluded. For rain noise, the noise level at a rainfall of 25 mm/hr should not exceed the Internal ambient noise level values in Table 1 plus 5 dBA.

Table 2 – Airborne and impact sound insulation requirements

Room		Sound insulation		
		Maximum impact insulation rating, $L'_{nT,w}$	Source room activity noise	Receiving space noise tolerance
AS 2107 Educational Buildings	*also applicable to:*			
Art/craft studios		60	Average	Medium
Assembly halls up to 250 seats		60	High	Low
Assembly halls over 250 seats		60	High	Low
Audio-visual areas		60	High	Low
Computer rooms – Teaching		60	Average	Low
Computer rooms – Laboratories		60	Average	Medium
Conference room		55	Average	Low
Corridors and lobbies		65	Average	High
Drama Studios	Dance Studios	55	High	Very low
Duplicating rooms/stores		65	High	High
Engineering workshops		65	High	High
Gymnasiums		65	High	Medium
Interview/counselling rooms		55	Average	Low
Laboratories – Teaching		60	Average	Low
Laboratories – Working		65	Average	Medium
Lecture rooms – up to 50 seats		60	Average	Low
Lecture theatres – without speech reinforcement		55	Average	Very low
Lecture theatres – with speech reinforcement		55	Average	Low
Libraries – General areas		55	Low	Low
Libraries – Reading areas		55	Low	Low
Libraries – Stack areas		65	Average	Medium
Manual arts workshops		65	Average	Medium
Medical rooms (First aid)		60	Average	Low

Room		Sound insulation		
		Maximum impact insulation rating, $L'_{nT,w}$	**Source room activity noise**	**Receiving space noise tolerance**
Music practice rooms		55	Very high	Low
Music studios		55	Very high	Very low
Office areas	Study rooms	60	Low	Low
Professional and administrative offices		60	Low	Low
Teaching spaces – Primary schools		55	Average	Low
Teaching spaces – Secondary schools		55	Average	Low
Staff common rooms		65	Average	Medium
Toilet/change/showers		-	Average	High
Other AS 2107 rooms				
AS 2107 Educational Buildings	*also applicable to:*			
General office areas (Office Buildings)	Open plan teaching spaces	60	Average	Medium
Other				
Teaching spaces – Hearing impaired		55	Average	Very Low
Swimming pools		65	High	High
Plant rooms		-	High	High
Nursery school – Play rooms		65	High	Low
Nursery school – Quiet rooms		60	Low	Low
Atria		65	Average	Medium

Table 3 – Sound insulation ratings for interfaces without pass doors, $D_{nT,w}$ dB

		Activity noise in source room			
Min D_{nTw}		**Low**	**Average**	**High**	**Very High**
Noise tolerance in receiving room	**High**	30	35	45	55
	Medium	35	40	50	55
	Low	40	45	55	55
	Very low	45	50	55	60

Note: Where doors are proposed between spaces consideration must be given to the placement and performance requirements of the door since the rating for doors with no acoustic treatment are not likely to exceed D_{nTw} 20 while standard solid core doors with full perimeter acoustic seals could achieve a rating up to D_{nTw} 35.

Table 4 – Performance standard for speech intelligibility in open-plan spaces – Speech Transmission Index (STI)

Room type	Speech transmission index (STI)
Open-plan teaching and study spaces	> 0.60

5.0 REFERENCE DOCUMENTS

This document provides the details of criteria recommended by the Association of Australasian Acoustical Consultants (AAAC) covering 3 main areas namely; recommended noise levels, recommended reverberation times and sound insulation between areas of high to low noise tolerance adjacent to rooms with low to high activity noise.

The development of this guideline has drawn heavily on the Australian Standard AS 2107-2000 *Acoustics – Recommended design sound levels and reverberation times for building interiors*. Whilst this standard recommends noise levels for certain spaces, it is not comprehensive and as a result, this guideline provides criteria for additional spaces commonly encountered in training and educational facilities.

Other areas of this document such as the recommended reverberation times and the floor impact and sound insulation requirements draw heavily from work conducted by BRANZ as well as from the DFES document BB93 which has been incorporated into Part E of the UK Building Regulations 2003.

6.0 ACOUSTIC TERMINOLOGY

Suitable measured noise levels are set out in AS2107.2000, being LAeq measured over a representative period.

Floor impact transmission may be described using the rating $L'_{n,Tw}$. This represents the measured sound level from a standardised tapping machine used generate noise into the room below. The lower the noise level the better the insulation against floor impact noise.

Transmission lost is the degree of airborne sound insulation between two adjacent spaces and may be quantified with the descriptor $D_{nT,w}$. $D_{nT,w}$. It is an international measure and is described as the weighted standardized sound level difference.

Reverberation time of a room is, for a sound of a given frequency or frequency band, the time that would be required for the reverberantly decaying sound pressure level in the room to decrease by 60 decibels.

Speech transmission index (STI) is a measure for the transmission quality of speech with respect to intelligibility. A value of 0 indicates completely unintelligible speech while a value of 1 indicates perfectly intelligible speech.

Signal-to-noise ratio (S/N) is the intelligibility of speech determined by comparing the loudness of the voice (signal) to the loudness of background sound (noise). The difference in decibels between the signal and the noise levels is known as the signal-to-noise ratio. As the signal-to-noise ratio increases, the signal becomes more intelligible.

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