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CLASSROOM ACOUSTICS - THE WAY AHEAD

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1. CLASSROOMS - AN INTRODUCTION

"Each Room or other space in a school building shall have the acoustic conditions and the insulation against disturbance by noise appropriate to its normal use"

The School Premises Regulations[1]

This statement precedes Section A of Building Bulletin 87: Guidelines For Environmental Design in Schools[2]. Section A, Acoustics, deals with Noise Control and Reverberation Times in classrooms. But what does this statement mean? what is meant by the terms 'acoustic conditions' and 'insulation against disturbance by noise'? From the results of our recently completed research project 'Speech Intelligibility in Classrooms', only a few classrooms would meet the requirements of this statement. Good classroom acoustics should generally include a low background noise level, an acceptable reverberation time and good speech intelligibility, that is, the ability to hear and understand what is being said (by both the teacher and pupils).

When I recently discussed the matter of classroom acoustics with a group of architects who were involved with the design of a group of academic buildings including primary schools, their answer to my question on what guidelines do they use for the design of classrooms was "guidelines?, do not use any guidelines - this is *always* the way that we have done it before"; what books do you use? "None, because there are none available". When pushed further as to what design criteria are used for the school design and materials for the school building, their answer was rather surprising - "as long as the school gets an award and gets its pictures in the glossy magazines"! This approach would appear to be quite common.

This highlights the problems that many professionals who are involved with the refurbishment or design of educational buildings have - the lack of information that is available to them. There may be guidelines, there may be criteria etc. but translating a series of numerical values into a working school building, that is acceptable for both teachers and pupils, is quite a different matter.

2. SCHOOLS BUILDINGS: FACTS AND FIGURES

Table 1 presents some facts and figures on the number of schools that exist in the United Kingdom as at January 1998. This is not the number of school buildings as one school may comprise of a number of different units. This table highlights the enormity of the problem. Also, the design of schools has changed dramatically over the last few years: many modern school buildings use lightweight materials for the roof and wall cladding. The internal layout has also changed from the cellular style of classrooms to either semi-open plan or full open plan classrooms.

Table 1: School Facts (January 1998)[3]
There are 33,543 schools in the UK: 1477 Nursery schools; 23,516 Primary schools; 8550 Secondary schools.
Funded as follows (DfEE figures): 415 Grant maintained primary schools; 23101 Local education authority controlled primary schools 634 Grant maintained secondary schools 3845 Local education authority controlled secondary schools 2433 Non-maintained mainstream schools 1638 Special needs schools
Government pledged funding for schools (since election in May 1997): £2bn New deal for schools in July 1997 budget (£1.3 bn for capital works) £1.083bn Capital grant direct to local authorities for spending on education £0.922 bn in credit approvals to allow local authorities to borrow specifically for school work

3. GOOD CLASSROOM DESIGN

Recently we were asked to undertake an appraisal of the acoustics of two new school buildings to be constructed in Edinburgh at Donaldson's College For The Deaf, which is the National Centre for The Deaf in Scotland. The two buildings - one a Nursery/Primary School and the other a Technology Centre are to be used for the education of school children who may be either hearing impaired and/or have language difficulties. Room acoustics, especially the reverberation time and the background noise levels of the various teaching spaces, are particularly important within buildings of this nature. The design of the two buildings were complete, but someone, somewhere mentioned that word: acoustics. Bells started ringing especially in the architect's office - acoustics, what about acoustics?. This is when we were asked to help out. For example, using the information provided by the architects the predicted reverberation time within most of the teaching spaces calculated to be 0.18 seconds. The majority of the classrooms were designed as conventional rectangular shapes, so emphasis was placed on the reverberation time of the rooms, the background noise levels and the general layout of the buildings.

Selecting the appropriate criteria to use, especially for a school for the deaf, was rather interesting. Table 2 highlights some of the recommendations available. There is quite a large range; however many of the sources do not stipulate whether the rooms are occupied or empty, whether the recommendations are for normal hearing or hearing impaired children. Certainly Building Bulletin 87 provides the most information, however the reverberation time for teaching spaces used by hearing impaired children other than classrooms is not specified. The reverberation times for other spaces used by hearing impaired children was reduced by 0.2 seconds in line with a similar reduction for classrooms. Other spaces included speech assessment/tutorial rooms.

Table 2: Comparison of Different Criteria For Classroom Acoustics

		Normal Hearing		Hearing Impaired	
Source	Room	R.T. (seconds)	B.N.L. (dB(A))	R.T. (seconds)	B.N.L (dB(A))
B. B. 87[2]	Classroom Hall Prac. Space	0.5 - 0.8 0.8 - 1.2 0.5 - 0.8	40 35 45	0.3 - 0.6 0.6 - 1.0* 0.3 - 0.6*	30 25 35
B. B. 25[4]	Classrooms	0.5 - 0.75	30 35		
RNID[5]	Classroom Artistic			0.5 (125 - 4000)	< 35 < 45
Barron, USA[6]				0.4	30 S/N: 20 dB
Crandell, USA[7]				0.4	30 - 35
Berg, USA[8]				0.3	
H.I. Child & School, UK[9]				0.5	S/N: 30 dB
Min. Of Env. Finland[10]		0.6 - 0.9	35		
Speech-Lang., USA[11]		0.4	30 S/N: 15 dB NC: 20		
BS 8205, UK[12]	Classrooms Workshops	<100 m^3: 0.5 <1000 m^3: 1.0	40 45		
BS 8233, UK[13]	Classrooms Workshops		$L_{Aeq,T}$ 45 $L_{Aeq,T}$ 50		
Smith, UK[14]			NC: 25		
Fry, UK[15]			NR: 25/35		

Great care must be emphasised in selecting the appropriate criteria as there is quite a range of different parameters used. Every practical noise source, both externally and internally generated, was considered for the building appraisal. Table 3 presents some of the noise sources that have been encountered in classrooms. These have been categorised into internal noise (within the classroom), internal noise (outwith the classroom but within the school) and external noise.

Table 3: Typical Noise Sources Found In Classrooms

Internal (Classroom)	Internal (School)	External (School)
Heating systems (e.g. warm air systems) Ventilation fans Computers Printers Impact on floor Impact on desk tops Rain noise on rooflights Rain noise on metal roofs Roof cracking (thermal expansion) Mechanical opening devices for windows Overhead projectors Birds (on rooflights) Fluorescent fittings Technology based equipment	Voices (from corridors) Impact noise (doors closing) Impact noise from floors Airborne noise (through demountable partitions) Singing Gymnastics Music Period bells Trolleys	Traffic noise: vehicles, aircraft, trains, helicopters Grass cutting equipment Trees Wind noise Empty HGV's on speed reducing devices Rain impact noise on building components

One source of external noise that is potentially a problem with the Donaldson's buildings is noise created by trees. The site chosen is 10 m away from a line of protected trees: all of the classrooms are on the perimeter of the building, around a central core, used as an activity area. The classrooms are to be naturally ventilated thus the use of large window areas with the addition of rooflights in some classrooms to give additional natural light. During a windy, warm day the internal noise level may increase noticeably: to check this, measurements were taken in an existing temporary classroom which is located on the site of the new building.

Table 4 shows a series of measurements that have been carried out in existing classrooms in which hearing impaired children are taught. The noise from the trees was evident is the classroom. These noise levels are similar to those found in the main study.

Table 4: Various Sound Levels Within Temporary Classrooms at Site of New Building, Donaldson's College For The Deaf, Edinburgh	
Activity	Sound Level (L_{Aeq}) dB
Activity Reading: 1 teacher, 3 pupils	62.5
Special needs class: 2 teachers, 3 pupils	72.2
Nursery: 1 teacher, 2 children	67.7
Corridor (wind noise plus aircraft)	49.6
Corridor (wind noise no aircraft)	35.8

One of the buildings to be constructed at Donaldson's is a Technology Centre where specific technology based subjects will be taught. These include Food and Fabric, Art and Design and Technology and Product Design. Obtaining information on the noise levels created by certain machines was very difficult so measurements were carried out on similar equipment located in a nearby school. Table 5 shows the noise levels of the machines whilst idling and also when operating on specific material.

Table 5: Typical Sound Pressure Levels in Technology Block (Stewart Melville's College, Edinburgh)		
Activity	Sound Pressure Level L_{Aeq} dB (Machine idling)	Sound Pressure Level L_{Aeq} dB (Machine cutting)
Background noise level	38.0	n/a
RJH Band facer	76.6	83.2 (mdf board)
Startrite bandsaw	66.0	85.3 (polystyrene)
Startrite bandsaw		80.9 (acrylic)
APTC bobbin sander	64.7	70.6 (mdf)
APTC bobbin sander		70.2 (acrylic)
Polishing machine	58.9	65.1 (acrylic)
Fortec former	75.1	
Briton scroll saw	65.9	81.7
Jig saw + band facer + bobbin sander + dust extract	78.0 (centre of room)	

The measurements were taken at a point 1.0 metre from the machine. Therefore, the actual level at the operators ear location is expected to be 3.0 dB(A) higher. Certain machines are loud and exceed the

First Action Level of 85 dB(A); but these are similar machines to those that are to be installed in the Technology Centre which is going to be used for the education of hearing impairment school children. What is the recommended level in this instance? It is recommended that a noise assessment be carried out in these noisy areas once the equipment but has been installed. Since Building Bulletin 87 recommends that the background noise level by reduced by 10 dB for hearing impaired children, then it is suggested that the First Action Level be reduced by 10 dB to 75 dB and similarly the Second Action Level be reduced to 80 dB.

4.0 POTENTIAL NOISE SOURCES

"Acoustic problems should be considered at the earliest stage of design. Appropriate planning of space use, including the separating of noise-sensitive from noise producing spaces, can eliminate many acoustic problems".

BS 8233:1987 Sound Insulation and Noise Reduction For Buildings

During the research project it became very apparent that many of the noise sources encountered could of been 'designed out' during the initial design stage of the building. Also many of the everyday noise sources could be reduced either through good maintenance or through a change in work practice.

The following are some of the potential sources of noise, which if not dealt with at the design stage, may increase the noise level within the classrooms of the new buildings:

a. Rain impacting on the sheet metal roof. The sound reduction index of the roof has been increased to take into account the special needs of the occupants in the rooms below. Rain impact noise appears to be an increasing problem. Recent discussions with architects have mentioned some schools where lessons stop when it rains due to the increased internal noise level from the roof.

b. There are numerous rooflights scattered around the buildings: special impact resisting glass used in a double lazing configuration is to be used to reduce rain impact noise. Rain impacting on the glass or on the metal flashing surrounding the rooflight can be a source of noise. At one school in Edinburgh near the coast, seagulls regularly roosted on the rooflights of a school which was an unusual source of noise and disturbance.

c. To reduce direct sunlight penetration into the classrooms, an aluminium canopy is to be constructed around the perimeter of both buildings. This canopy is likely to be very noisy in the event of rain with noise entering the building through three paths: through open windows, through openings at the top of wall where the canopy meets the wall and through the supporting steelwork.

d. General internal layout: location of quiet areas next to noisy areas but yet there are no means of separating the two areas. The design of the Technology Block in particular has a number of areas where noisy events are likely to occur but no effort has been made to reduce noise transmitting to other areas of the building.

5.0 CONCLUSION

It would appear from the literature available and also from the research that has recently been carried out in schools, classroom acoustics is very much an 'add on' extra and seldom taken into consideration during the initial design stages. This is certainly the case for two new buildings to be constructed in Edinburgh, even although the units are to be constructed for the education of hearing impaired children where the acoustics of the teaching spaces is of paramount importance. There is no doubt that architects and designers of schools have a difficult time as there is very little information available to them to make the design of classrooms easy. Not only is choosing the right parameter difficult enough but also the correct numerical value.

6.0 REFERENCES

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