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Acoustic Design of Schools

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1. Introduction

1.1 The New Part E of Schedule 1 of the Building Regulations 2000 (as amended by SI 2002/2871) makes it a legal requirement to design and build new school buildings to meet appropriate acoustic standards. Building Bulletin 93 sets out the normal way to comply. It will also be a requirement to provide comprehensive documentation to the building control authority to demonstrate that the design complies.

1.2 The acoustic requirements are given in Section 1 of Building Bulletin 93 (BB93).

Section 1 also gives recommendations for suitable acoustic testing to prove good workmanship. This is not a requirement under the Building Regulations. However, BB93 recommends that those procuring the building of a school, referred to as the 'client', should include a requirement for acoustic testing in the building contract.

1.3 BB93 was published in July 2003, although the text of Section 1 was made available in March 2003. It replaces Building Bulletin 87. BB87 is a guidance document giving both quantitative and qualitative recommendations, but there has been no legal requirement to follow this guidance.

1.4 The draft of the rest of BB93 is a large and comprehensive document, the scope of which is outside the legal requirements of the Building Regulations.

- Sections 2 to 5 give guidance and recommendations for good practice in the design of school buildings for good acoustics. Specific recommendations are given for critical areas such as music rooms and drama studios.

- Section 6 gives guidance and recommendations on sound reinforcement, electronic/radio hearing aids and acoustic design in order to better integrate children with hearing impairment into the general classroom.

- Section 7 describes a number of case studies in which different acoustic problems reported in schools have been investigated and overcome in the design or by incorporating remedial measures.

1.5 The new Regulations came into force on 1st July 2003. It is necessary to demonstrate compliance with the requirements in Section 1 of BB93. In addition, it is open to those procuring the building of the school to specify in the contract that the recommendations given in some or all of Sections 2 to 6 be incorporated in the design.

2. Acoustic Performance Standards

Acoustic performance standards are specified for the following:

- ambient noise levels in spaces
- airborne sound insulation between spaces
- impact sound transmission of floors to spaces below
- reverberation times in teaching and study spaces
- areas of sound absorbing finishes in circulation spaces
- speech intelligibility in open-plan spaces

If it is considered that special circumstances make some of the acoustic standards inappropriate, then an application to vary them can be made to Building Control for their consideration. The application must be supported with a written report by a specialist acoustic consultant, giving reasons for the proposed changes in standards.

Where performance standards are given for ancillary areas these are to be considered only as guidance.

2.1 Ambient Noise Limits

The aim is to limit extraneous noise so that it does not interfere with teaching. The limits apply to existing or sources of noise that are known about, and for which the levels can be predicted reasonably accurately. They do not apply to the noise caused by activities in the school itself which cannot be accurately determined in advance.

2.1.1 Ambient noise is defined as the total noise from all external sources intruding into the school added to the noise from the schools own ventilation or other plant. This includes noise from road, rail and air traffic and industrial/commercial premises. It does not include noise from school activities such as teaching or sports, nor teaching equipment such as computers or fume cupboards.

2.1.2 The ambient noise limit must be achieved with adequate ventilation. The word adequate has caused confusion. Dfes have issued a clarification which explains the situation, until Part F is next revised.

i) For Building Control purposes, ambient noise to be achieved with background ventilation (400mm^2/m^2 of floor area).

ii) Client to specify through construction contract the ambient noise limit with ventilation rate for normal occupancy.

2.1.3 The standard is set in terms of the average noise level (L_{Aeq}) over the noisiest 30 minute period during the school day. Upper limits are tabulated for the different types of room found in schools.

2.1.4 Noise from building services plant which is intermittent, tonal or impulsive must be at least 5 dB less than the relevant upper limit.

2.1.5 There is also a limit set on the 'maximum' noise level in most teaching and study areas. Here noise levels are not to regularly exceed 55 dB $L_{A1\text{-}30min}$.

2.1.6 There is a requirement to minimise the noise of rainfall on lightweight roofs. No limit is set, but methods of control must be included and justified to Building Control.

2.2 Airborne Sound Insulation Between Rooms

The aim is to provide enough sound insulation so that noise from normal school activities is not likely to interfere with teaching in adjacent rooms.

2.2.1 BB93 specifies the minimum sound insulation to be achieved between adjacent rooms. The same values apply whether the adjacent rooms are next to each other, on the same floor, or one above the other.

2.2.2 Rooms are categorised by the type of activity in two ways:

- how noisy, from "Low" to "Very High"
- how tolerant of intruding noise, from "Very Low" to "High".

The sound insulation specified depends on the noisiness of each room in relation to the tolerance of its neighbour. If two rooms A and B have different activities, the requirement may be more onerous when considering noise from A to B than from B to A. For example noise from a woodworking classroom intruding into a general classroom requires greater sound

insulation than noise from a general classroom intruding into a woodworking classroom.

The design always has to consider sound travelling in either direction and cater for the worse case.

2.2.3 The standard for airborne sound insulation is set in terms of normalised weighted noise level difference ($D_{nT,w}$) between rooms that are completed and finished. The reverberation time assumed is the upper limit specified for the room into which the noise is intruding. Depending on which rooms are next to each other, the required $D_{nT,w}$ ranges from 30 dB to 60 dB.

2.2.4 The noise level difference depends not only the sound coming directly through the separating wall or floor, but also on sound travelling along direct paths between two rooms. For example, sound can enter the inner leaf of an external wall, travel along the wall and then out into the next room.

Therefore, to achieve a specific noise level difference, sound travelling along all possible indirect paths (known as flanking paths) must be taken into account. This can include ceiling voids, ventilation ductwork, internal flank walls and service penetrations.

2.3 Airborne Sound Insulation from Corridors and Stairwells

The aim is to prevent noise from activities in corridors and stairwells interfering with teaching. Providing good sound insulation between each room and a common corridor also greatly reduces the risk of sound from a very noisy activity escaping along a corridor. This sound could then get into rooms further along or on the opposite side of the corridor.

2.3.1 For corridors and stairwells, BB93 does <u>not</u> specify the sound insulation that has to be achieved on site in the completed building. Instead the minimum sound reduction rating (R_w), as measured in a test laboratory, is specified for the wall (including glazing) and the door. There is no requirement to take flanking sound paths into account.

A value is given for both wall and door. Higher sound reductions are specified for music rooms. For practical reasons the sound reduction rating required of the door is less than that of the wall containing it. The overall sound reduction achieved will lie between the two values.

2.3.2 There may be air vents between a room and corridor, perhaps as part of a natural ventilation scheme. If so a minimum sound insulation ($D_{n,e,w}$) is specified for each vent, depending on the number of vents. A higher value is specified for music rooms

2.4 Impact Sound Transmission

The aim is to prevent footfalls from the floor above interfering with teaching.

2.4.1 BB93 specifies the maximum level of impact sound that would be generated on separating floors. The limit specified depends only on the type(s) of room below each floor. Rooms are categorised by their sensitivity to impact noise.

2.4.2 The standard for impact sound insulation is set in terms of the apparent weighted impact sound level ($L'_{nT,w}$). This is the level of impact noise that would be made by a standard impact (tapping) machine operating on the floor. The reverberation time assumed is the upper limit specified for the room below. The limits specified range from 55dB to 65dB.

2.5 Reverberation Times

The aim is to provide good acoustic conditions for listening to speech or music.

2.5.1 Reverberation times are specified for all rooms that may be used for teaching or performance. The rooms are to be furnished but unoccupied. For each type of room an upper limit is given below which the reverberation time is acceptable. For some music rooms both upper and lower limits are given for the reverberation time.

2.5.2 Achieving reverberation times within a specified range will require design of the room finishes and furnishing to give the right amount of sound absorption, not too little and not too much.

2.5.3 The standard is set in terms of a mid frequency reverberation time (T_{mf}) which is the average of the reverberation times at the octave band frequencies 500Hz, 1kHz and 2kHz.

2.5.4 If large halls are to be used for the performance of unamplified music, there is a requirement to seek specialist advice on appropriate sound absorption.

2.6 Absorptive Finishes in Circulation Areas

The aim is to limit the build up of noise in corridors and stairwells, so reducing the potential for the noise to intrude into teaching areas.

2.6.1 An adequate area of sound absorbing finish must be installed in corridors and stairwells. Two methods of calculation are given which can be used to show that there is enough absorption.

2.7 Speech Intelligibility in Open Plan Areas

The aim is to allow clear speech communication in open-plan teaching and study areas.

2.7.1 Speech intelligibility is specified for teachers talking to students, students to teachers and students to students.

2.7.2 The standard is a minimum Speech Transmission Index (STI) of 0.6.

2.7.3 An 'activity plan' must be drawn up, agreed with the client and lodged with Building Control. This contains information that affects speech intelligibility including:

- locations of teachers and students, seating plan.
- numbers of teachers giving presentations and students discussing at one time.
- numbers of people walking through the area during teaching/study periods.
- equipment / machinery operating.

2.7.4 The activity plan is used to predict noise levels from the activities. This must be included in a prediction model to calculate STIs.

2.7.5 For a given activity plan, it may not be possible to achieve the required STI. The activity plan must not be adjusted to fit but instead:

- the necessity for open plan areas be reconsidered
- if necessary, movable walls be installed to allow separate rooms to be formed.

The separate rooms should comply with the acoustic criteria corresponding to their use. Adequate sound insulation will require top of the range movable walls and other measured that may prove impracticable.

3. Demonstration of Compliance to Building Control

Not only should a school be designed to the specified acoustic standards, but this is to be demonstrated to the Building Control Authority.

How this should normally be done is given in BB93. This specifies a list of plans and information to be given to Building Control.

3.1 Information Required

3.1.1 Plans and documents showing full construction details and material specifications.

3.1.2 A set of plans marked with the following information:

i) The intruding ambient noise level in each room.

ii) The weighted normalised noise level difference between each adjacent room, in both directions.

iii) The sound reduction values (R_w) for corridor walls and doors and ($D_{n,e,w}$) for vents.

iv) For each room that is underneath another room, the weighted normalised impact sound transmission level of the separating floor.

v) The mid frequency reverberation time in each room.

vi) Estimated range of STI values for teacher to student, student to teacher and student to student.

In each case the plans should be marked with both the values calculated for the design and the corresponding standard specified in BB93.

The set of plans must also show:

vii) The absorptive treatment proposed for corridors and stairwells.

3.1.3 Calculations showing how values of the following were derived.

i) Airborne sound insulation between rooms ($D_{nT,w}$).

ii) Impact sound transmission ($L'_{nT,w}$).

iii) Reverberation times (T_{mf}).

iv) Areas of absorption in corridors and stairwells.

v) Rain noise control measures.

There does not appear to be a specific requirement to provide calculation of intruding noise. It is not clear whether calculations are required for every calculated value, as shown on the plans, or if sample calculations will be adequate.

3.1.4 Documentation, including acoustic test certificates and reports to justify the acoustic values used in the calculations and the sound reduction ratings of the corridor walls and doors. There is a database of sound reduction values and sound absorption coefficients published in association with BB93 which presumably could be used without further justification.

3.1.5 The activity plan and layout for open plan areas, on which the STI calculations were based.

4. Demonstration of Compliance to Client

4.1 BB93 recommends that the client, who is having the school built, includes a requirement for acoustic testing in the building contract. This is recommended because achieving good acoustics, particularly sound insulation, is very dependent on careful workmanship not only having the right design.

The situation is considered to be similar to house building, where it has been found that when tested the sound insulation between dwellings often falls short of what the design ought to achieve.

4.2 Remedial measures will be required to put right any failures in testing. Therefore, it is recommended that sample set of rooms are completed early for advance testing. Lessons learnt from these tests may then be able to be incorporated in the construction of the rest of the school.

4.3 It is recommended that eventually the following tests are done in one out of four cases:

- ambient noise levels in teaching and/or study rooms including some on the noisiest facade
- airborne sound insulation between adjacent spaces, both through walls and floors; the receiving rooms being for teaching and/or study
- impact sound transmission into teaching and/or study rooms
- mid-frequency reverberation times

4.4 Speech Transmission Index measurements should also be taken in open plan areas, at one in ten student positions. Measurements to be made teacher to student, student to teacher and student to student. Measurements must be made with simulated ambient and activity noise as if the area were occupied and in use. These noise levels will have been agreed and submitted to Building Control at the design stage.

The following sections relate to the guidance given in Sections 2 to 9 of the draft BB93. Revised texts of these sections are due to be published in succession over the coming weeks.

5. Guidance and Recommendations for Good Practice

Sections 2 to 5 of BB93 give guidance and recommendations for good practice in the design of school buildings to achieve good acoustics. These are not legal requirements under Part E of the Building Regulations. It remains to be seen to what extent specific recommendations that go further than the requirements of Part E become part of the contractual requirements between the contractor and his employer.

5.1 Section 2 - Noise Control

This section mainly comprises advice and technical information about measuring, assessing and controlling external and ventilation plant noise. It is recommended that:

- A noise survey is done and high levels of external noise reduced if possible for example by an earth bund.
- A vibration survey is done if close to a railway or very close to a road with many heavy goods vehicle movements.
- Layout of the school is arranged to protect noise sensitive areas from both external noise and noisy activities within the school.
- To help children with hearing impairment, there should be an additional limit on low frequency ambient noise.

5.2 Section 3 - Sound Insulation

This section gives advice on calculation of sound intrusion and sound insulation between areas. Information is given on the sound insulation of various constructions and how to allow for flanking sound paths.

There is extensive advice about ventilation of schools. If possible, schools should have natural ventilation. Where schools are on noisy sites, natural ventilation by opening windows will result in excessive noise intrusion. This is an important potential conflict, so advice is given on different ways to have natural ventilation without greatly reducing the sound insulation of the building envelope. On particularly noisy sites, mechanical ventilation may be the only solution.

5.3 Section 4 - Room Acoustics for Speech

Advice is given on calculation of reverberation times from sound absorption coefficients, and the absorption characteristics of various materials.

There is a recommendation about how sound absorbing materials are best distributed about a room. The aim of this is to achieve better acoustics, particularly for speech, beyond just achieving acceptable reverberation times.

5.4 Section 5 - Music

Comprehensive advice is given on the design of the acoustics of music rooms. This include recommendations about

- relative locations of rooms for different instruments, and the appropriate degree of flexibility in the use of each room.
- distribution of sound absorbing materials
- sound diffusers and early reflections
- Layout of different types of music room

All these recommendations are outside the requirements of Part E.

5.5 Section 6 - Special Hearing Requirements

This section gives advice on the provision and use of electronic hearing aids and radio aids for children with hearing impairment. It is considered that there are more children with a significant hearing impairment than previously acknowledged, and that most of the children ought to be taught in mainstream schools. For this to be successful, measures are required to aid the intelligibility of the spoken word for them.

Sound field systems are alternatively known as speech reinforcement systems. Advice is given on these to help the speech intelligibility particularly in large halls or to help children with hearing impairment. However, they are not to be installed as an alternative to providing good natural acoustics.

5.6 Section 7 - Case Histories

BB93 contains a section of case histories. These look at existing situations where there have been acoustic problems. The solutions illustrate the principle of good acoustic design. Example calculations are given.