AN OVERVIEW OF ON SITE TEST RESULTS OF CLASSROOM CORRIDOR WALLS, INCLUDING THE EFFECTS OF DOORS, GLAZING AND VENTILATORS, POST BB93

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1.0 INTRODUCTION

Cross ventilation is an extremely effective form of ventilation and often the most cost effective method of ventilating a classroom, due to the potential reduction in the floor to ceiling height. This paper therefore looks at the on site performance levels of corridor walls adjacent to classrooms. The findings within this paper demonstrate that BB93's required 40 dB $D_{n,e,W}$ for a vens can be reduced to 35 dB $D_{n,e,W}$ without a significant reduction in the over all performance of these partitions.

Due to the complexity in measuring the $D_{n,e,W}$ of a vent, a proposal is made as to how to convert between insertion loss and $D_{n,e,W}$.

2.0 THE ACOUSTIC PERFORMANCE OF CORRIDOR WALLS

Since the introduction of BB93 [1], the following performance standards are required to be adhered to:

Type of space used by students	**Minimum *R*w (dB)**		**Minimum *D*n,e,w –10lg*N(dB)***
	Wall including any glazing	Doorset	
All spaces except music rooms	40	30	40

Table 1: BB93 Performance standards for airborne sound insulation between circulation spaces and other spaces used by students - minimum sound reduction index, *R*w and minimum *D*n,e,w –10lg*N* (laboratory measurements)

It is complex to measure/calculate the on site performance of these partitions due to the irregular nature of circulation spaces. As a result, these performance requirements are based upon lab tested sound insulation levels, of the elements making up these partitions.

$D_{n,e,w}$ specification for vents relates to the weighted, normalised, sound pressure level, across a specified small element, in this case, a vent of a specific size. If the vent is increased, the difference in sound pressure level across the vent will also decrease. As such, BB93 contains a correction for when using more than one vent.

BS EN ISO 140-10 [2] provides the requirements for determining the $D_{n,e,w}$ levels of a vent. In summary, this standard requires that vents be tested between two reverberant chambers and have a surface area of less than $1m^2$. Several issues arise with respect to these requirements:

a) Cross ventilators typically have an open area of $0.75m^2$ – $1.5m^2$, depending upon the Building Services needs. A free area of 50% or less is typical to achieve the specified levels of attenuation. This brings the minimum size of these ventilators to $1.5m^2$, in other words, these ventilators are always larger than the $1m^2$ specified by BS ISO 140-10.
b) The author is not aware of an off the shelf ventilator achieving 40 dB $D_{n,e,w}$, along with the ventilation requirements for cross ventilation. On the other hand, it has been shown that it is possible to use a combination of lined ducts, conventional attenuators, plenums and other elements, to provide adequate levels of attenuation across such vents, see School H and a BRE report [3]. The design and specification of such systems is typically based around insertion losses. It is important to note that there is no direct conversion between insertion loss and $D_{n,e,w}$.

To over come these limitations, it is proposed that a standard, CIBCE cross talk calculation be undertaken across a proposed ventilator, based upon calculated/measured insertion losses for the given parts of a ventilator. From here, it is proposed that the calculated $D_{n,e,w}$ can be determined.

2.1 Alternative Performance Standards for Ventilators Considering the Effects of On Site Tolerance Levels for Doors

Taking a typical 7.5m wide 2.5m high classroom, with a 2.4m^2 ventilator, it can be shown that the combined R_w level of the 40 dB partition and 30 dB door alone, will achieve R_w 39 dB. The combined sound reduction of this corridor wall in combination with a 40 dB $D_{n,e,w}$ vent, will result in a partition achieving 36 dB D_W, assuming zero on site tolerance levels for doors and other elements.

Based upon the results in Section 5.0, it can be seen that corridor walls (corridor to classroom) typically achieve 29 dB D_W and at best achieve 33 dB D_W. On this basis, it can be calculated that the on site tolerance levels of doors is between 8 dB at best, and 12 dB typically.

Using these on site tolerance levels, it can be shown that the acoustic performance of the ventilators can be reduced to 35 dB $D_{n,e,w}$, with only the smallest reduction in performance to the separating wall, 1 dB. It is therefore seen that the benefits in achieving cross ventilation, comfortably out way the 1 dB reduction in performance on site.

3.0 TEST PROCEDURE

To determine the acoustic performance of corridor walls, a test procedure was required. Importantly, a test method was needed, which would allow the comparison of results between schools, irrespective of the school layout.

According to ISO 140-14 [5], geometrically complicated spaces should be used as the source room. As the atriums fitted into this category and were also very large, it was difficult to provide the right sound field in the room. Due to this, it was decided that measurements would be taken in both directions for each partition.

3.1 Testing from Corridors / Atriums to Classrooms

Testing difficulties arise when dealing with geometrically complicated spaces, such as atriums and circulation spaces. As such acoustic testing was carried out to ISO 140-14, although it was difficult to comply with this standard, as a result of narrow path ways being the only accessible spaces within atriums and many circulation spaces. Only having a narrow path way meant that loudspeaker positions had to be placed relatively close to the measured partition. Therefore, the method described in Section A.4.2 in ISO 140-14, which is used to measure doors between a corridor and a room, was altered slightly to include the partition and not just the door.

Two loudspeakers were used simultaneously and placed 1m either side of the common partition and a equal distance away from the partition. Loudspeakers were placed facing each other, causing the sound field not to be diffuse, though it is thought that little variation in the frequency response would be seen at the partition. If the loudspeakers were facing away from the partition, the higher frequency directivity of the speakers may provide varying sound pressure levels along the length of the partition. As such, a direct field would be incident on the classroom door. According to the standards, this is not ideal, but is thought to more accurately portray real life activities, such as students walking past.

Measurements in the source room where carried out by use of a continuously moving microphone. The path spanned the length of the common partition and ran 1m from the partition being tested. Measurements in the receiving room consisted of five fixed positions as to ISO 140-4 [6].

3.2 Testing from Classrooms to Corridors / Atriums

This required assimilation of Section A.3.2 in ISO 140-4 regarding damped receiver rooms, and led to the procedure measuring the receiving room sound pressure level, between 0.5m and 1m away from the common partition. Measurements where taken along the length of said partition, such that measurements concerning corridors and atria were as similar as possible and allowed for the sound power transmitted through the partition to be accurately measured.

Two loudspeakers were used simultaneously and placed near to each rear corner of the classroom. A continuously moving microphone was used to measure source room levels, and five fixed microphone positions were used in the receiving room. These were equally spaced along the length of the common partition and 1m away from this partition.

4.0 SITE ASSESSMENTS

The aim of this paper has been to establish the on site acoustic performance of walls to corridors and particularly concentrating on the performance of doors and ventilators for cross ventilation. To do this, three schools where tested, where these schools either employed signal sided ventilation or cross ventilation via open roof lights. The second set of five schools, employed cross ventilation into an atrium or corridor space. The names of schools tested have not been used, which was one of the requirements specified by some of the schools/contractors, prior to undertake testing.

The list below provides a brief description of each of these schools, along with site observations:

School A – A large, new secondary school employing single sided ventilation. This school consists of an atrium located in the centre of the school, with three wings breaking off from it. The majority of the classrooms are located in each wing, with a few located around the perimeter of the atrium.

Solid 30 dB doors have been used throughout this development, in combination with stud walls. Vision panels comprising of 4/100/4 (assumed) glazing with an approximate area of $1m^2$, where incorporated in corridor walls, see Pic 7

> **Site Observations** - This school was the only school which was seen to be affected by poor build quality. Large gaps had been left above partitions hidden by ceiling tiles, such to allow the passage of services. In some instances, plasterboard had not been taken to the underside of the slab, See Pics 8 and 9. In many instances, the threshold seals to doors failed to drop or correctly seal with the floor finish. A variety of perimeter seals to doors where used throughout this development.

School B – A single storey new primary school, comprising 11 classrooms. The school employs cross vent through windows and open able roof lights. All teaching spaces open off a large central corridor.

Solid 30 dB doors which incorporated vision panels where used throughout this development. The threshold seal was a drop seal in combination with a threshold strip. Compression seals where used to the remaining three edges of the door.

> **Site Observations** - A good, high quality school. The sound insulation of corridor walls was limited by the doors, principally at the head-leading edge of the door and at the threshold.

School C - A single storey new primary school, comprising 13 classrooms. The school employs cross vent through open able roof lights. The layout of the school meant that classrooms open off short corridors and a large open plan area. This school also employed cloakrooms between classrooms.

The rated 30 dB doors used twin fixed wiper seals at the base, but no threshold. The large vision panels where located next to doors, incorporating 16.8mm laminated glass.

> **Site Observations** – Same findings as School B,

School D – A large school designed prior to the introduction of BB93. This school contains a two/three storey street, see Pic 11. The school used cross ventilation through classrooms and into the street. The vents to the atrium where simple open able flaps, with no attenuation, see Pic 10.

Doors are unlikely to have been rated to 30 dB, but where still of a very high quality. Doors where formed from aluminium frames in combination with heavy glazing, see Pic 12. The door threshold was not sealed, but all other edges where sealed with compression gaskets.

Site Observations – The open unattenuated ventilator provided unsatisfactory levels of sound attenuation. Multiple complaints from users where reported. These vents where said to have limited the performance of the school due to noise. One of the key design requirements was to have staggered teaching times. This was not possible, due to noise ingress into classrooms when pupils where moving between lessons within the central street.

When vents where closed, the doors where the weak point in partitions, see Section 6.0 on Aluminium Doors for further details.

School E – A classroom block within a Secondary School, comprising 8 classrooms. This block was designed prior to BB93. Ventilation was achieved through open able windows and 300mm by 300mm unattenuated vents, to a centrally ventilated corridor. There was no way of closing these vents.

This block used heavy solid doors with a glazed panel to the head. Similar glazed panels where used along the classroom wall, see Pic 13.

Site Observations – The unattenuated vent significantly compromised the performance of walls to corridors, although there had been no complaints from teachers.

School F - large school designed when BB93 was in a draft format. The school was therefore designed with the intent to comply with BB93. A large long atrium was used at this school, which housed the reception lobby, with classrooms surrounding the space. A further two atria were partitioned off from the main one and each housed 12+ classrooms. Cross ventilation was achieved via attenuated openings or windows and bespoke attenuated vents located adjacent to the central atrium, see Figure 1, and Pics 14 and 15.

R_W 30 dB solid doors where placed next to a very large glazed panel, formed from 16.8mm laminated glass. The remainder of the wall was formed from stud work.

Site Observations – When vents where closed, the limiting factor was again the doors. When the vents where open, sound insulation was noticeably effected by the vents. Although, it was felt that attenuated vents still provided adequate levels of privacy, the acoustic performance of these partitions was still better than many cases where cross ventilation was not used.

School G - A large school designed when BB93 was in a draft format. The school was therefore designed with the intent to comply with BB93. This school is two storeys high and consists of one main walk way spanning the length of the school, with six atria stemming off the promenade, each containing about 12 classrooms. Cross ventilation of sorts was used throughout the school. Air was expelled from all classrooms via attenuated vents to a similar design as that used within School E, see Pics 17 and 18.

R_W 30 dB doors incorporating a glazed panel and drop seals where used throughout this development.

Site Observations – Same findings as School E. Interestingly within this school, vent operating handles in all classrooms had been removed by the schools management. This is taken to mean that the school was happy with the level of separation offered by the open ventilators.

School H – A Technology Block within a Secondary School, comprising 9 teaching spaces. Teaching spaces are arranged around a central atrium. The ventilation is achieved via open able windows and cross ventilation to the Atrium.

R_W 30 dB doors containing a large vertical glazed panel, where used throughout this school. Cross talk across the ventilation system was achieved by designing a bespoke system, using the guidance provided by CIBCE, see Figure 2 and Pics 19 and 20.

Site Observations – Corridor walls and ventilators provided an equal performance to that of a school employing single sided ventilation. As always, the sound insulation was limited by the door, principally at the threshold. No sound could be heard coming from the ventilators.

All schools have been designed to comply with BB93, unless otherwise stated.

5.0 RESULTS

The table below provides the results of on site testing, these results demonstrate similar levels of sound insulation across partitions of equal type, giving confidence to the test method. Additionally, there is little difference between measurements taken between corridors and classrooms and vice versa, again, giving confidence that the D_w performance of the partition has been determined accurately.

All School Doors and Vents Closed	**Min**	**Max**	**Mean**	**St dv**	**N**
Corridor to Classroom	25	33	29	2	14
Classroom to Corridor	26	34	31	3	8
All School - Doors Pushed and Sealed					
Corridor to Classroom	29	35	32	3	5
Classroom to Corridor	29	36	33	3	4
School D – Open Vents					
Corridor to Classroom 50%	19	20	19	1	3
Corridor to Classroom 100%	18	19	18	1	3
Classroom to Corridor 50%	18	19	19	1	2
Classroom to Corridor 100%	17	18	18	1	2
School E – Open Vents					
Corridor to Classroom 100%	21	22	22	1	2
Classroom to Corridor 100%	21	23	22	1	2
School F and G – Open Vents					
Corridor to Classroom 50%	28	31	30	1	7
Corridor to Classroom 100%	27	30	29	1	7
Classroom to Corridor 50%	28	31	30	1	5
Classroom to Corridor 100%	27	30	28	1	5
School H – Open Vents					
Corridor to Classroom 100%	30	33	31	2	3
As above, door pushed and sealed	31	36	34	3	3
Classroom to Corridor 100%	30	35	33	2	5
As above, door pushed and sealed	35	37	36	1	4

Table 2. Results of on site testing of corridor walls

6.0 CONCLUSION BASED UPON A SITE REVIEW

Door Review - Across all schools, it was observed that the doors limited the performance of walls to corridors. Significantly, it was felt that the fabric of the doors, whether they included a vision panel or not, was not the limiting factor of the door. The compromising element in almost all cases was the acoustic performance of the door seals. Three of the main faults are listed below:

Threshold Seals - The over riding compromising factor to corridor walls was gaps under doors. These gaps primarily occurred due to doors being cut short, meaning that the drop seal or wiper blades did not make contact with the floor finish or threshold strip. This fault is estimated to occur on 25 – 50% of doors to classrooms,

A pair of wiper blades in combination within a threshold strip, provided the best results. This was followed by a single blade wiper seal, in combination with a threshold strip. Drop seals provided by far the worst performance. Drop seals have a tendency not to drop or only drop on one side; problems arise as a result of small objects getting stuck in the drop seal mechanisms; if the gap between the door and frame was too large, the drop pin remains partially compressed resulting in the seal not dropping; other faults occurred as a result of gaps, when the straight wiper seal dropped onto an uneven floor finish. It is estimated that 25 – 40% of doors to classrooms where compromised by a fault associated with this type seal, see Pics 1 and 2.

Head-Leading Edge of the Door - In many instances, the head-leading edge of the door, did not make contact with the door rebate, see Pic 7. In most cases, doors bent away from the door rebate. It is seen that 10 - 25% of doors where limited by this detail.

Perimeter Strips - Providing these seals where fitted correctly and made contact with the appropriate elements, they worked well, see Pics 3 to 6.

On the other hand, it was seen that 25-50% of the door locks, hinges, door closers and other elements, broke those seals, resulting in the acoustic performance of these seals being compromised.

In summary, it is estimated that 75% of doors where comprised by a fault associated with door seals, particularly relating to on site fixtures and fittings.

Aluminium Doors - Aluminium doors where used on one of the schools, School D. It is advised against using these doors since the leading edge of the door tended to be damaged/bent, preventing the doors from closing correctly.

Workmanship – Overall, it was felt that workmanship did not significantly affect the solid elements of these walls. Only in one school did workmanship relating to the acoustic performance of the partition.

Ventilators

From both auditory, subjective assessments and on site tests, it is clear that an unattenuated vent will provide completely unsatisfactory levels of sound reduction across partitions to corridors.

The level difference across the ventilator within Schools F and G, is assumed to provide no more than 30 dB $D_{n,e,w}$. From the on site test results, it can be seen that the partitions within this school, on average, had an equal performance to schools not employing cross ventilation. On site testing also shows that the maximum performance of these partitions was down by 2-3 dB compared to schools without vents.

School H clearly shows from test results and a subjective auditory assessment, that cross ventilation is possible without compromising the performance of corridor walls.

7.0 CONCLUSION

It has been shown that on site tolerance levels of doors is typically 12 dB, and 8 dB at best. The short fall in these doors comes as a result of poor sealing around doors, principally at the threshold. In most cases, this seal is comprised by the fact that the door is cut too short, hence the wiper seal does not make contact with the floor finish or threshold strip. Additionally, many of the drop seals used failed to operate correctly.

As a result of doors failing to meet equal levels to those in the lab, it is foreseen that a 5 dB reduction in the acoustic performance of the ventilator will result in a single dB reduction in the overall performance of the separating wall to corridors. This compromise is seen to be comfortably balanced by the benefits of cross ventilation.

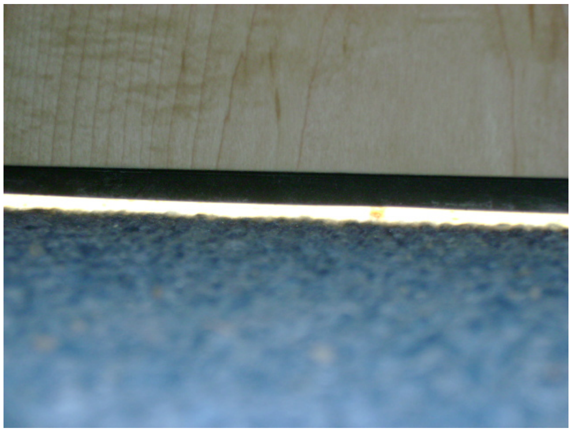
Over all, it is seen that corridor walls provided adequate levels of acoustic protection, even though the on site levels are significantly lower than those specified by BB93. This statement is made on the basis on a lack of complaints.

Finally, since there is no direct conversion between $D_{n,e,w}$ levels and insertion losses, it is proposed that a CIBCE cross talk calculation be undertaken across the ventilator alone, such to establish a calculated $D_{n,e,w}$ level for the ventilator.

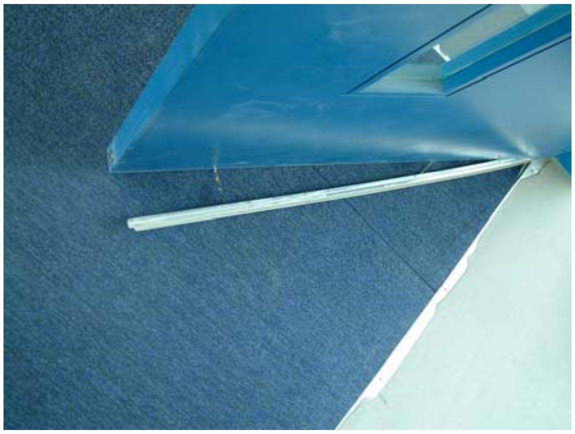
8.0 REFERENCES

1. BB93 – Building Bulletin 93: Acoustic design of schools – A design Guide, July 2004.
2. BS EN 20140-10:1992 Acoustics – Measurement of sound insulation in buildings and of building elements. Part 10. Laboratory measurement of airborne sound insulation of small building elements: Sound Insulation and airflow measurements, Dec 04.
3. BRE Client Report: A prototype ventilator for cross ventilation in schools: Sound insulation and airflow measurements, Dec 04.

4. BS EN 20140-14: 1992 Acoustics – Measurement of sound insulation in buildings and of building elements, Part 14, Guidelines for special situations in the field.
5. BS EN ISO 140-4:1998 Acoustics – Measurement of sound insulation in buildings and of building elements. Part 4. Field measurements of airborne sound insulation between rooms.



Pic 1. Drop seal falling short of the floor finish



Pic2. Drop seal pulled out from under door

Pic 3. Hinges cutting through wiper seals – correct detail on the right

Pic 4. Door locks cutting through wiper seals – correct detail on the right

Pic 5. Large gap between double and leaf & a half doors – a very common fault

Pic 6. Double door containing cover plate between doors,
Such to ensure the performance of such doors

Pic 7. Gap – Door head-leading edge bending away from the door rebate,
A common fault

Pic 8. Poorly sealed service penetration

Pic 9. Plasterboard missing at the top of partitions

Pic 9. Poor detailing around a Vison Panel

Pic 10. Un-attenuated vent to central Atrium – School D

Pic 11. Large central street within School D

Pic. 12 Doors within School D

Pic 13. Corridor walls including un-attenuated vent – School E

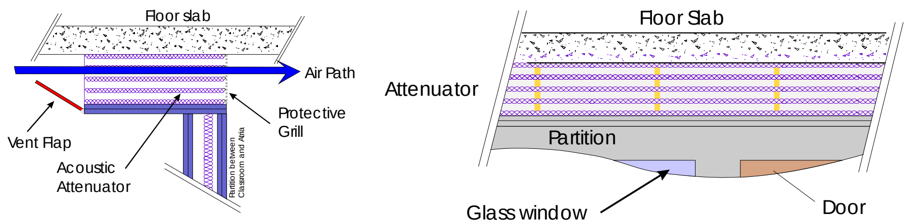
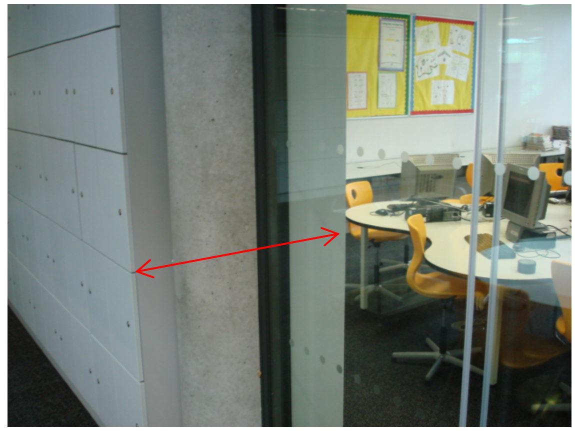


Figure 1. Bespoke attenuator used within Schools F and G

Pic 14. Vents within Atrium of School F

Pic 15. Vents within classrooms - School F



Pic 16. Illustration of corridor wall widths – School F

Pic 17. Vents within atrium of School G

Pic 18. Vents within classroom – Vent open within left hand side image – School G

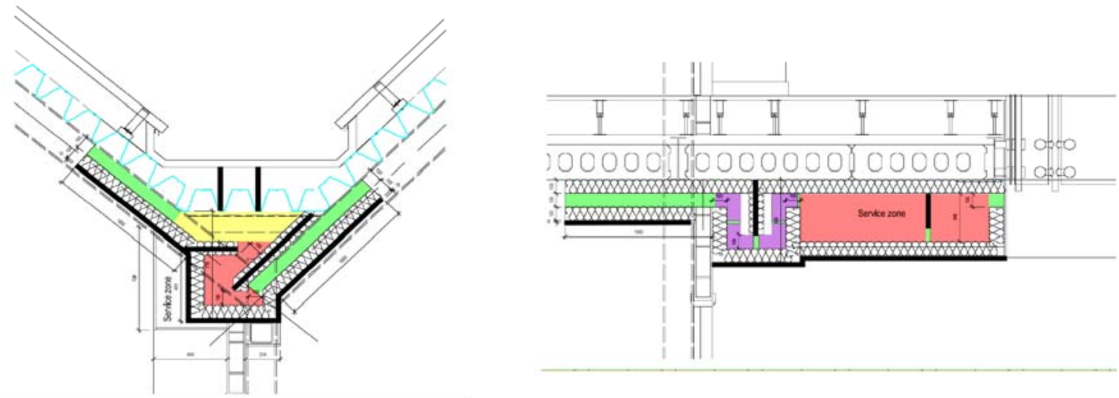


Figure 2. Section through bespoke attenuator – Left first floor – Right Ground Floor – School H

Pic 19. Attenuator ventilator within classroom Ground Floor – School H

Pic 20. Attenuator ventilator within Classroom First Floor – School H