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SOME ACOUSTIC ISSUES IN OPEN PLAN SCHOOLS

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1 INTRODUCTION

One of the assumptions in the Building Bulletin 93 is that internal activity noise will be dealt with by sound insulation between rooms and therefore does not include contributions of activity noise in the assessment of classroom ambient noise levels limit of 35dB $L_{Aeq, 30mins}$. This presents a number of possible problems not least that educators and designers are still looking to open-plan designs to offer economy and flexibility of space use. The result is that there may not be the necessary sound insulation between rooms that the Bulletin assumes unless, of course, open plan spaces are 'banned' in new schools design. Unfortunately it seems unlikely that this will be the case, even though the Building Bulletin discourages the use of open plan teaching and the call for detailed acoustic modeling will be hampered by the lack of information in the Bulletin relating to the performance of such spaces, the levels of noise generated by open school activities and so on. In fact Building Bulletin 51: "Acoustics in Educational Buildings" (1975) went further than the last two bulletins in discussing design issues of open plan schools.

This paper therefore reviews research carried out some 30 years ago, when open plan schools were first introduced in significant numbers into mid and secondary education. It is worth pointing out that, at that time, open plan schools acoustics were not considered by the Department of Education and Science and the BRE to present any significant problems in terms of communication and comfort. For this reason there was no imperative to, nor interest in, publishing the results of that research at that time, even though it was clear that the information revealed could be useful to designers.

The research was carried out by the author of this paper for a doctoral / masters programme at Nottingham University and the resultant thesis lodged in the Library of that University – where, perhaps, it may still be found[1]. The work was carried out before computers were in general use, hence the fact that diagrams are scanned in with inevitable quality losses and the acoustic equipment used, whilst amongst the best available at that time, seems now incredibly labour intensive. Many will remember 'with fondness' the time they spent laboriously analyzing data in real time using high speed level recorders fitted with B&K's relatively new Statistical Distribution Analyser.

2 RESEARCH PROJECT REVIEW

2.1 Open Plan Schools

In the late 60's and early 70's of the last century a range of open plan schools were built to meet the needs of new teaching methods, notably "integrated day" teaching and to maximise flexibility of the use of space. It should also be noted that a driver towards open planning was the benefit of using what had formerly been corridor spaces between rooms as general activity / wet areas, in other words, using them for teaching rather than merely for movement. This economic is still found driving contemporary school designs. Many open plan schools were designed for primary teaching but later a number of schools, notably in the (then) West Riding of Yorkshire, were built for use as Middle Schools. The first of these was the Delf Hill Middle School in Bradford which is described in some

detail in Building Bulletin 35 (1966), as it was a DES Design Unit project. The plan of this school is shown in Figure 1. This school was used as a pilot for the main research study which then examined Grimethorpe Middle School the first of a series of 8 open plan middle schools built in the 70's in the West Riding. Plans to survey a further school in the series were disrupted by the miners strike in 1972.

The open plan forms of these schools were similar, indeed they were all variations on the Delf Hill theme. However, the detailed planning of the two schools was significantly different with Grimethorpe School (see Figure 2) having sliding partitions to close off teaching spaces from general activity areas whilst Delf Hill School employed much wider use of carpet on teaching space floors (not in activity areas). In addition Delf Hill Middle School was in an urban location and was exposed to some intrusive road traffic noise, whilst Grimethorpe Middle School was in a rural location with little road traffic close to it.

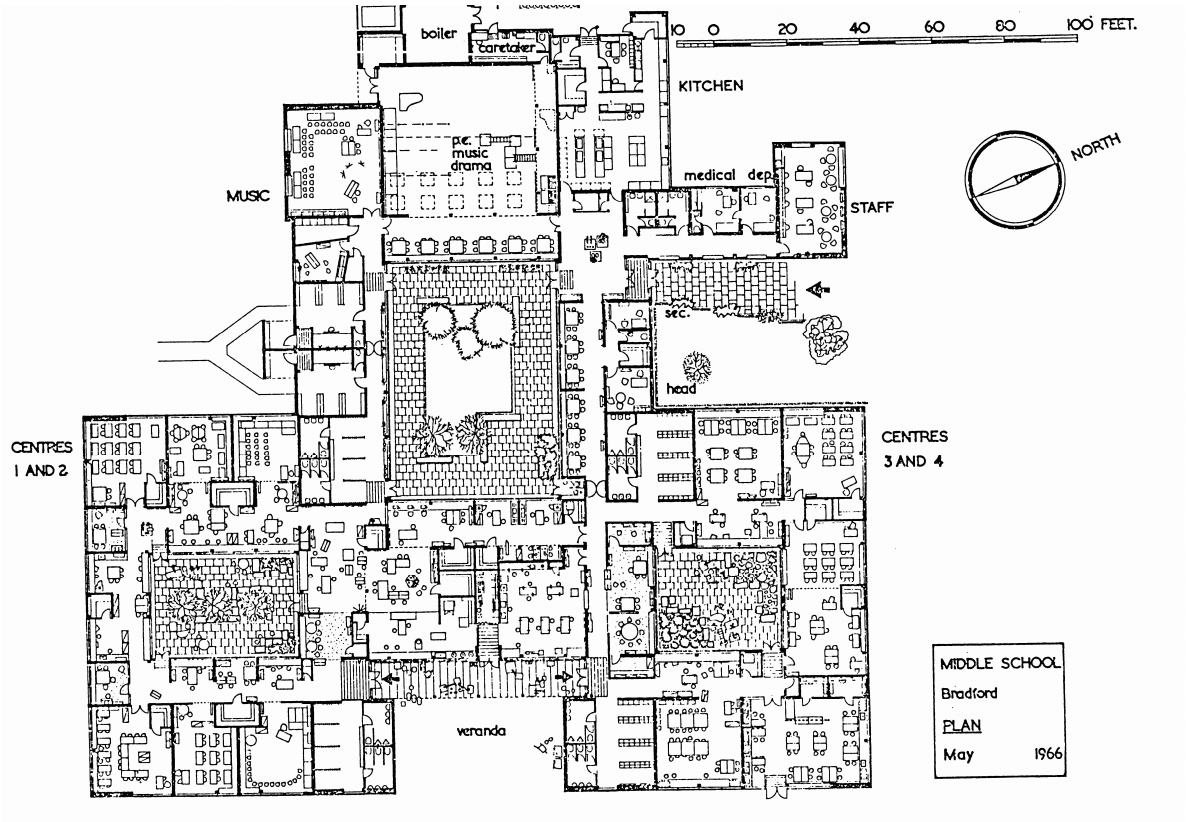

Figure 1 Plan of Delf Hill Middle School

2.2 The Research in Brief

The two schools from were studied in some detail (6 days of surveys in the pilot study, 4 days per week for 4 weeks in the main study) to establish internal sound levels in a range of spaces and covering various uses / activities and to derive 'reliable' descriptors of internal sound levels and other measures to inform design.

The main surveys were carried out using 4 microphones linked with screened miniature co-ax cables to a control unit which contained a Nagra (Kudelski) IVF reel-to-reel tape recorder and 4 electrical make-and-break timing devices operating telephone exchange type indirect relays. This enabled remote sampling sequentially of four locations throughout each school day for a total of 14 days (4 days per week for 3.5 weeks). Each sample was 1 minute in duration with a short pause after each series of 4 to enable identification of sample groups at analysis. Indicator lights showed

which of the four microphones were sampling the sound field at any time and the B&K Type 4117 microphones, fitted with random incidence correctors, were located around the schools in areas within or adjacent to the main teaching spaces. These were powered by battery driven locally placed preamps and were mounted on robust purpose made stands which included anti-knock / anti-vibration isolation. Cabling back to the central console was via the suspended ceiling system, to prevent 'accidental' tampering / damage. Tapes and microphones were selected to provide low levels of cumulative error in the system which was calculated to be some ±1.75dB. For the pilot survey longer term recordings were made so that sampling rates et alia could be developed for the main study. These were selected to provide samples at each location for 1 minute in 10 minutes. Two Nagra based systems were used to record in a variety of locations over a number of days. These systems had a cumulative error of approximately ±1.21dB. Calibration of each microphone/ tape link was carried out at the beginning and end of each day of sampling. In fact the way the control console was designed and the limitations of available timers and relays led to sampling, in the main study, at 1 minute in approximately every 4.5minutes - a sample rate of some 22%.

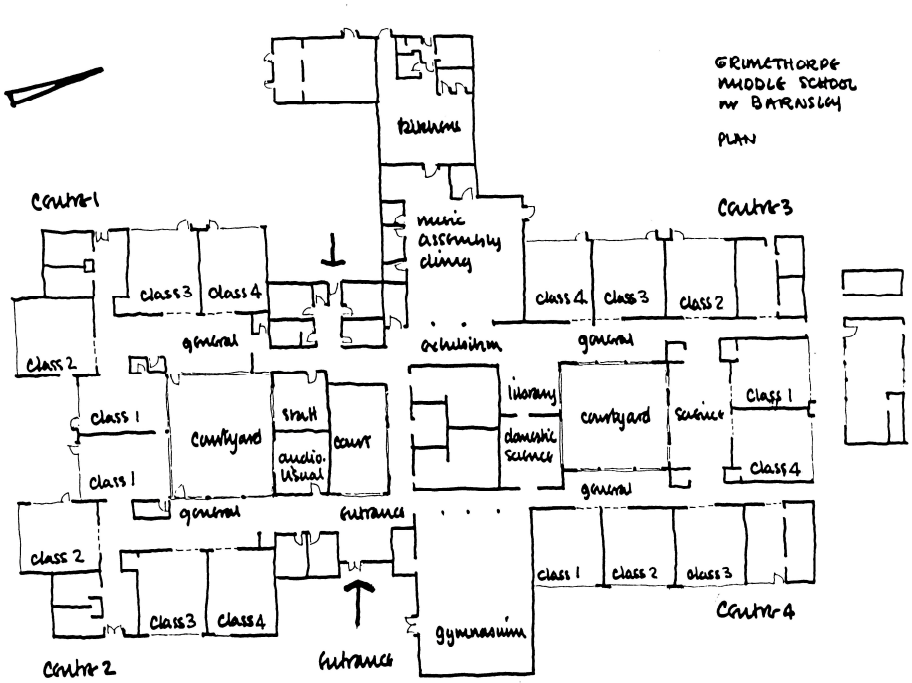

Figure 2: Plan of Grimethorpe MS

During the sampling / recording times questionnaires were administered to school children and teaching staff to establish basic responses and attitudes to acoustic environment.

In addition reverberation times were measured in a variety of spaces in each school as were attenuation losses through the open plan spaces. These were all measured in octave bands and for linear responses.

After completion of the field-work laboratory analysis of the tapes was carried out to establish:

- Modal levels (most frequently occurring levels)
- L_{10} and L_{90} levels
- Sound spectra

each for occupied and unoccupied spaces (identified sample by sample) using a B&K Type 2305 High Speed Level Recorder in combination with a Type 4420 Statistical Distribution Analyser and, as appropriate, Frequency Analyser (Type 2107).

The sound spectra were then used, together with the values obtained for modal, L_{10} and L_{90} levels to establish the Articulation Index and related communication rating for each condition. [Note: L_{eq} was not at this time a descriptor in general use largely because without computing power it was not easy to deal with. It is difficult now to remember but hand-held calculators capable of providing logarithms at the touch of a button only really came into general use in the mid-seventies. The introduction of integrating sound level meters and Noise Level Analyzers in the 80's made a significant difference to our ability to apply L_{eq} to measurements.]

Needless to say the analysis of the taped recordings was a lengthy process.

2.3 The Research Findings - Data

This paper can only provide summarised findings from the research – if more detail is required it would be possible to provide this by means of photocopies of a rather 'dog-eared' copy of the research thesis. Detailed statistical analysis of the cumulative data provided mean values, standard error values and from these the 95% and 99% confidence levels. For the Delf Hill shool with data analysed at a 10% sample rate:

Noise Generation		dB(A) - occupied	Articulation Index	Communication Rating
	Modal levels	57.8	0.38	Fair
	L_{10} levels	64.9	0.09	Minimal
	L_{90} levels	53.1	0.52	Good
Attenuation (Lin)	13dB / doubling of distance (over approximately 30 metres)			
Mean Reverberation Times (Lin)			Occupied	Unoccupied
	Open plan Classrooms		0.42 secs	0.61 secs
	General activity areas		0.46 secs	0.61 secs

Table 1: Data from Delf Hill School

Confidence levels for the noise generation data were of the order of:

	95%	99%
Modal:	±0.36 dB(A)	±0.54 dB(A)
L10:	±0.46 dB(A)	±0.69 dB(A)
L90:	±0.46 dB(A)	±0.69 dB(A)

Noise Generation		dB(A) - occupied	dB(A) - unoccupied	Articulation Index (occ)	Communication Rating (occ)
	Modal levels	61.4	50.9	0.25	Poor
	L_{10} levels	68.8	56.9	0.03	Nil
	L_{90} levels	56.2	48.7	0.43	Fair
Attenuation (Lin)	3dB / doubling of distance over approximately 10 metres				
Mean Reverberation Times (Lin)				Occupied	Unoccupied
	Open plan Classrooms			0.5secs	0.5secs
	General activity areas			0.47secs	0.62secs

Table 2: Data from Grimethorpe Middle School

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Confidence levels for the noise generation data were of the order of:

	95%	99%
Modal:	±0.42 dB(A)	±0.63 dB(A)
L10:	±0.48 dB(A)	±0.72 dB(A)
L90:	±0.32 dB(A)	±0.48 dB(A)

2.4 The Research Findings – Subjective Responses

Summaries of some responses to questions relating to noise at Grimethorpe School are given below:

		Year 1	Year 2	Year 3	Year 4	**Overall**
QUESTION 1:Adjectival check list yes no responses Do you think this word describes your school?						
Quiet	Yes %	53.6	40.7	41.9	31.9	**42.4**
	No %	46.4	59.3	58.1	68.1	**57.6**
Noisy	Yes %	46.4	69.5	46.5	51.1	**54.1**
	No %	53.6	30.5	53.5	48.9	**45.9**
QUESTION 4:Is your school generally …… ? If it could be changed would you like it to be ….?						
School generally	Noisy %	39.3	54.2	41.9	42.6	**4.9**
School generally	Quiet %	60.7	45.8	58.1	55.3	**54.6**
If changed	Noisier%	O	0	2.3	2.1	**1.0**
	Quieter %	55.4	44.1	37.2	38.3	**44.4**
	Same%	44.6	55.9	60.5	57.4	**54.1**
QUESTION 5: Is your classroom generally …… ? If it could be changed would you like it to be ….?						
Classroom generally	noisy %	50	78.0	58.1	42.6	**58.0**
Classroom generally	quiet %	50	22.0	41.9	57.4	**42.0**
If changed	Noisier %	1.8	0	2.3	2.1	**1.5**
	Quieter %	62.5	62.7	44.2	38.3	**53.2**
	Same %	35.7	37.3	53.5	59.6	**45.0**
QUESTION 6: Is your activity area generally …… ? If it could be changed would you like it to be ….?						
General area	Noisy %	39.3	47.5	32.6	38.3	**40**
	Quiet %	60.7	52.5	67.4	61.7	**60**
If changed	Noisier %	1.8	0	2.3	2.1	**1.5**
	Quieter %	48.2	52.5	32.6	36.2	**43.4**
	Same	50.0	47.5	65.1	61.7	**55.1**

	%					
QUESTION 7: How do you react to noise when working?						
Dislike noise when working %		89.3	94.9	95.3	95.7	**93.6**
Like noise when Working %		10.7	5.1	4.7	4.3	**5.9**

Table 3: Summary of Questionnaire results

2.5 Conclusions

The results of the studies demonstrated that communication conditions in general activity areas were not satisfactory and subjective responses showed that classrooms conditions were even worse. There were fairly serious problems to be dealt with in the design of open plan schools if this plan form were to be used in future school design. The conclusions were that designers should give further attention to a range of issues in developing school provision. The study identified some relevant issues, which included:

Communication Standard	**Sound levels in dB(A)**	
	L10	**Modal**
Maximum (for communication)	66	58
Mean	62	54
Minimum (for privacy)	58	50

These would lead to significant reductions in ambient levels during school activities.

Suggested design options included:

- Reduction in occupancy levels / more area per pupil (c.f. open-plan office design)
- Increased distances between noise producing area
- Increased use of absorbent surfaces (Grimethorpe had limited carpet provision) in floors, ceilings and partitions (focusing on 1000 to 4000 Hertz absorption)
- Reductions in reflective surfaces especially glazing (at this time schools were designed to a 2% daylight factor which produce very large areas of glazing)
- Isolation of very noisy areas e.g. music rooms, gymnasia, halls, etc
- Reduction of noise intrusion from road traffic et alia.

It was acknowledged that some of these solutions were unlikely to be “affordable”.

3 MORE RECENT FINDINGS

Involvement in recent school design projects has provided a limited a opportunity to check current generated internal, levels (quick samples over half-day visits).

Abernethy Primary School, nr Perth, Scotland

Levels in general activity areas close to open teaching areas, separated by partitions which do not extend to 1 metre approximately below ceiling level are given in Table. Floors carpeted, ceiling of perforated metal with absorptive linings. No specific vertical provision of absorption.

Location	**Area 1**	**Area 2**	**Area 3**	**Mean values / Differentials**
L_{10}	62.3	60.8	58.3	60.5
				2.7
L_{eq}	59.8	58.3	55.2	57.8

				2.6
L_{50}	57.3	55.6	52.6	55.2
				4.5
L_{90}	53.0	50.8	48.3	50.7

Table 4: Sound levels measured within general activity areas ay Abernethy

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Auchterarder Primary School, Perthshire, Scotland

Levels in general activity areas close to open teaching areas, separated by partitions which do extend ceiling level. Floors carpeted, ceiling with absorptive linings. No specific vertical provision of absorption.

Location	Area 1	Area 2	Area 3	Area 4	Area 5	Mean values / Differentials
L_{10}	50.6	74.1	67.3	66.1	63.2	64.3
						2.8
L_{eq}	47.9	70.9	64.9	63.3	60.3	61.5
						2.3
L_{50}	44.7	68.9	62.6	61.6	58.0	59.2
						4.3
L_{90}	41.2	63.1	58.3	57.7	53.9	54.8

Table 4: Sound levels measured within general activity areas ay Auchterarder

It is possible that approximations of L_{eq} values could be derived from the Grimethorpe / Delf Hill Data by applying the differentials derived from the above data above. It should be noted that mean, modal and L50 values will be the same for normally distributed data and in the above indications are that the distributions are near normal. Accordingly it would be possible tentatively suggest that L_{eq} levels will be some 3dB(A) above the L Accordingly it would be possible tentatively suggest that L_{eq} levels will be some 3dB(A) above the L50 levels obtained in the surveys at Delf Hill and Grimethorpe.

This may assist those wishing to model sound distributions in open plan schools and suggests that communication standards should relate to:

Communication Standard	Sound levels in dB(A)	
	L_{10}	L_{eq}
Maximum (for communication)	66	61
Mean	62	57
Minimum (for privacy)	58	53

This is, of course, based on the use of the “Articulation Index” – which remains a simple tool for design purposes.

4 REFERENCES

1. ‘Some Acoustic Problems of Open Plan Schools’; Nicholas C Smith, University of Nottingham, October 1974