

# CLASSROOM ACOUSTICS – RECENT EXPERIENCES

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## 1. INTRODUCTION

Major parts of renovated or new school buildings in Norway the last 5 to 6 years are built with open plan or base solutions (large classrooms). The main reason for this has been a new educational strategy. Open plan solutions were also popular about 30 years ago in Norway. Such solutions have not been evaluated with respect to acoustical properties. From our point of view, the new concept has been established without considering issues related to physical environment. SINTEF Building and Infrastructure has carried out several projects and evaluated other research work on this item. This paper presents some of the most important results and recommendations so far.

## 2. INVESTIGATIONS

An introduction to these studies was to evaluate other research work concerning acoustical properties. A literature investigation showed a number of research work on this item, especially in US and Great Britain. A small inquire investigation among some acoustical consultants in Norway was also carried out to get a state of the art concerning common solutions and general experiences. From this, essential results and recommendations were presented in a report for National Office for Building Technology and Administration (BE), se reference [1]. Results from this study beside earlier experiences and recommendations are used for a renewal of SINTEF Building and Infrastructure, Building Detail Sheet concerning classroom acoustics, se reference [2]. Several studies point on acoustically disadvantages with open plan solutions and a necessity to recommend for instance minimum levels on speech transmission index. Table 1 presents a definition of classroom size used in our studies and recommendations related to descriptions in Norwegian Standard, NS 8175 (1997).

Table 1. *Definition of classroom size*

NS 8175 type of room	Suggested size [m <sup>2</sup> ]
Standard classrooms	< 80
Base and open plan solutions	80 – 200
Large teaching areas or auditorium	> 200

Another part of studies presented here was an investigation combining subjective perception with acoustical measurements. The subjective perception contain an inquire investigation among school pupils supplied with interviews. Measurements of background noise levels and reverberation time were carried out in the school areas belonging to the interviewed pupils. The subjective perception investigation is based on method presented in [3] and further presented in chapter 3. Totally, these investigations contain studies of groups at 9 schools, here named Case 1 to 9. All the schools are new or renovated between 2002 and 2006.

### 3. SUBJECTIVE PERCEPTION

Reference [3] presents a guide for school environment investigations. This guide presents a simple method to map the indoor environment in public schools and present knowledge on a wide range of physical parameters relevant for such investigations. One important part of this is the inquiry of the pupils. At each item, the subjective score is ranged from 0, good/no symptoms to 3, unacceptable situation. Score 1 means some or medium symptoms, while 2 means medium or strong symptoms. Table 2 shows the main results from this subjective perception of the acoustical environment of Case 1 to 9.

Table 2. *Subjective evaluation of the acoustical environment of Case 1 to 9.*

Case	Subjective evaluation
1	1
2	1
3	1
4	2
5	0
6	0
7	2
8	2
9	2

The pupils classify Case 1, 2, 3, 5 and 6 with no or small (medium) symptoms. For the rest of the cases, the pupils classify the acoustical environment with score 2, i.e. medium or strong symptoms. Here we recommend efforts to improve the situation. None of the pupils in the 9 test cases has hearing impair. The subjective perception is of course the total impression of sound insulation, reverberation time, outdoor noise, noise from installations, “traffic” noise and also noise levels from pupils itself and educational activities. Except of the last two items, standardized measurements can give an objective classification of the acoustical environment.

### 4. REVERBERATION TIME

The reverberation time is measured at all schools according to NS-EN ISO 3382, in 1/1 octave band from 63 Hz to 8000 Hz. The measurements were carried out with the loudspeaker method and the operator in the room. The base solutions were furnished for the educational use but unoccupied. Essential information about the linings of the different rooms is given in table 3. All floor covering are of linoleum or vinyl. None of the walls has acoustical treatments. Beside different types of furniture, all acoustical covering is in the ceiling.

Table 3. Some characteristics of investigated base solutions.

Case	Wall linings	Ceiling lining
1	A)	Acoustical ceiling with perforated board
2	A)	B)
3	A) and partly masonry/concrete	B)
4	A)	B)
5	A) and masonry/concrete	B)
6	A) and masonry/concrete	B)
7	A) and masonry/concrete	B)
8	A) and partly masonry/concrete	B)
9	A) and partly masonry	Major part B), minor part unperforated steel sheets

A) Gypsum board

B) Lowered, acoustic ceiling of high density mineral wool

Figure 1 present measured, frequency dependent reverberation time of Case 1 to 9.

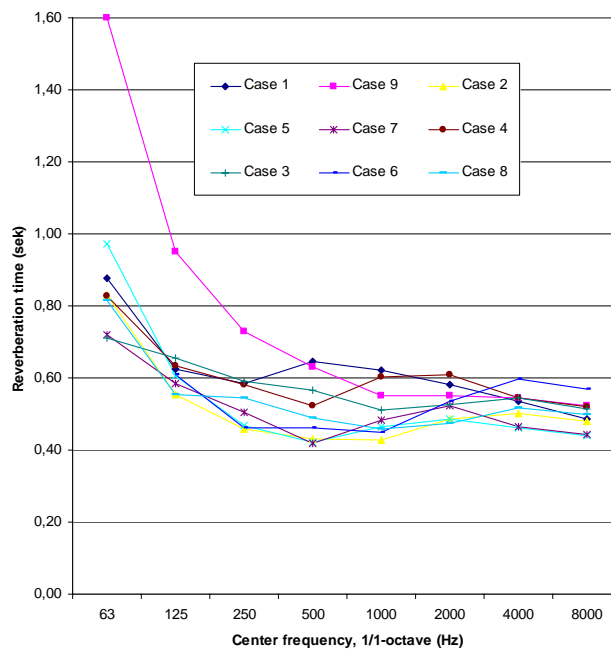


Figure 1. Reverberation time of Case 1 to 9.

In table 4, the average reverberation time is presented together with an evaluation of the results compared with requirements from NS 8175, sound class C.

Table 4. Reverberation time measurements compared with requirements from NS 8175

Case	Average reverberation time 63 to 4000 Hz	Fulfill limits in NS 8175 (1997) Sound class C		
		i)	ii)	iii)
1	0.64	Yes	No	No
2	0.53	Yes	Yes	No
3	0.59	Yes	Yes	No
4	0.62	Yes	No	No
5	0.55	Yes	Yes	No
6	0.52	Yes	Yes	No
7	0.53	Yes	Yes	No
8	0.55	Yes	Yes	No
9	0.79	Yes	No	No

i) Class rooms,  $T \leq 0.8$  sec in each octave band from 125 to 2000 Hz

ii) Class rooms for pupils with hearing impair or visual disturbances,  $T \leq 0.6$  sec in each octave band

iii) Open plan or base solutions,  $T \leq 0.4$  sec in each octave band from 250 to 2000 Hz

All measurement cases fulfill the requirements for ordinary classrooms, but none of them fulfill requirements concerning open plan or base solutions. Case number 1, 4 and 9 shows reverberation times above requirements concerning classrooms for pupils with a hearing impair or visual disturbances. The measurements also show that it is not possible to obtain a reverberation time of 0.4 sec only with acoustical treatment of the ceiling.

## 5. BACKGROUND NOISE LEVELS

The background noise levels is measured at all schools according to NS-EN ISO 16032, in 1/1 octave band from 31.5 Hz to 8000 Hz. The measurements were carried out only with the operator in the room. The rooms were furnished for the educational use with technical installations running normally. None of the measurement values has been affected by outdoor noise sources. Figure 2 presents measured background noise levels for Case 1 to 9.

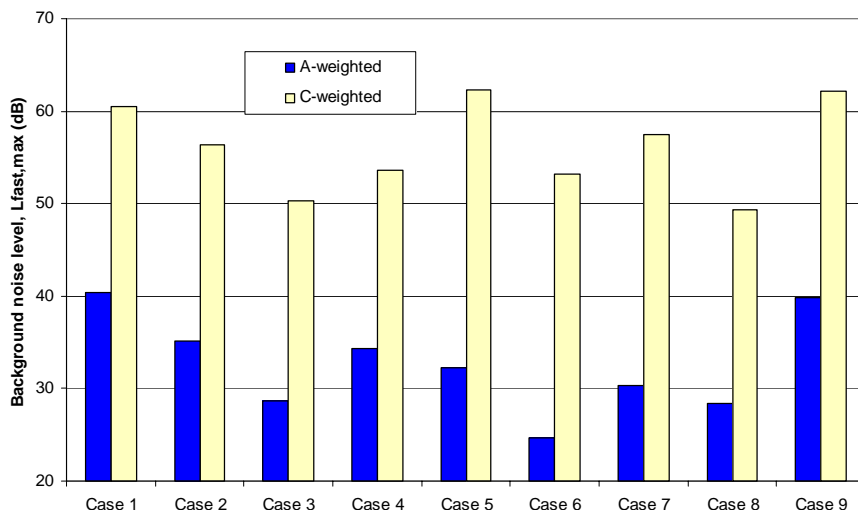


Figure 2. Background noise levels of Case 1 to 9.

In table 5, A-weighted background noise levels are presented together with an evaluation of the results compared with requirements in NS 8175, sound class C.

Table 5. *Background noise levels compared with requirements from NS 8175*

Case	Background noise level $L_{A,max}$ (dB)	Fulfil limits in NS 8175 (1997) Sound class C	
		i)	ii)
1	40	No	No
2	35	No	No
3	29	Yes	Yes
4	34	No	No
5	32	Yes	No
6	25	Yes	Yes
7	30	Yes	Yes
8	28	Yes	Yes
9	40	No	No

i) Educational rooms,  $L_{A,max} \leq 32$  dB

ii) Educational rooms for pupils with hearing impair or visual disturbances,  $L_{A,max} \leq 30$  dB

Case number 3, 5, 6, 7 and 8 fulfills limits in NS 8175 for educational rooms. All of these except Case 5 also fulfil the limit concerning rooms for pupils with hearing impair or visual disturbances. The other cases do not fulfil the requirement concerning noise levels from technical installations. Case number 1 and 9 shows rather high background noise levels.

## 6. EVALUATION OF RESULTS

Beside measurements of reverberation time (RT) and background noise levels (BNL), Case 1 to 9 has been evaluated with respect to how the room is suited for oral presentations (OP) and how the area is organized concerning spaces for circulation (SFC). The speech transmission index is of course a relevant parameter to quantify how the room is suited for oral presentations. Research work carried out by two students, see reference [4], concluded that a lot of measurements and evaluation is required. Other studies, for instance reference [5] verify that the speech transmission is strongly related to the reverberation time if the background noise level is acceptable low. In this project, only a subjective evaluation has been carried out to characterise the oral presentation possibilities, especially related to distances and reflecting surfaces in the room. Spaces for circulation will of course disturb the educational areas if the sound insulation between the areas is poor or missing. A simple study of how the area is organized makes it possible to characterise such noise disturbances.

The four parameters mentioned above are coupled together in a simple way. Each case is given 0 point when the parameter is satisfactory, 1 point when the parameter is rather unsatisfactory and  $\frac{1}{2}$  point for some negative result. Table 5 present these evaluation of the acoustical parameters together with the result from the subjective perception.

Table 5. *Evaluation of acoustical parameters*

Case	Subjective evaluation	Physical evaluation				
		RT	BNL	SFC	OP	$\Sigma$
1	1	1	1	0	0	2
2	1	0	0,5	0	0	0,5
3	1	0,5	0	0	0	0,5
4	2	1	0,5	0	0,5	2
5	0	0,5	0	0	0	0,5
6	0	0	0	0	0	0
7	2	0	0	0,5	0	0,5
8	2	0,5	0	0,5	0	1
9	2	1	1	1	0,5	3,5

Values from the physical evaluation above zero, raise an important point on parameters with negative symptoms, for instance 1 at the “BNL” and “SFC” of Case 9. The maximum “score” of the subjective evaluation is 3, and 4 of the physical evaluation. The concept presented in table 5 is of course a simple way of combining different evaluation parameters, in this case to compare it with the subjective evaluation. Comparing these two types of evaluation, differences larger than 0,5 is most interesting. Case 7 and 8 show lower symptoms from the physical evaluation compared with the subjective evaluation. The reason for this is not clarified, but a possibility is noise levels from pupils itself and educational activities. In Case 1 and 9, the physical evaluation show more severe symptoms than the subjective evaluation. Perhaps, either “RT” or “BNL” acts less intruding than the measurements show. Especially Case 9 show the necessity of improving the acoustical environment at the base solution.

## 7. CONCLUSIONS

Results from measurements show that even new school buildings do not fulfill requirements from the building regulations, both concerning reverberation time and background noise level. Evaluation also shows unsatisfactory solutions concerning how the room is suited for oral presentations and how the area is organized with respect to spaces for circulation. It is therefore important to increase the focus of acoustical properties among architects and construction engineers. Reverberation time measurements show that even if the room is furnished, it is not possible to obtain a reverberation time of 0.4 sec only with acoustical treatment of the ceiling.

Generally experiences so far are that traditional classrooms, group rooms or auditoriums are suitable for oral presentations. Base solutions can partly be suitable for presentations while open plan solutions and large education areas are generally not suited for oral presentations. Recommended sound absorption in the room increases with the room area, but then the possibilities of oral presentations of course decrease. It is necessary to achieve short reverberation time, for instance below 0.5 sec in base solutions. In large education areas we recommend certain limits concerning Speech Transmission Index and distance dependent damping, see reference [2]. It makes it necessary with acoustical planning in detail. Generally it is also very important to organize the area with proper sound insulation between educational rooms and spaces for circulation.

## 8. REFERENCES

- [1] NBI Report O 20642. *Acoustical environment at schools. Literature investigation and review of recommendations*. Norwegian Building Research Institute. Oslo, 2005 (in Norwegian).
- [2] SINTEF Building and Infrastructure. *Acoustical planning of school and kindergartens*. Building Detail sheet no. 527.305, 2006 (in Norwegian)
- [3] Jerkø, S. & al. (2006). *School environment for education – guide for school owners*. About indoor environment and the physical environment. Project report 404 - 2006. Norwegian Building Research Institute, Oslo 2006 (in Norwegian).
- [4] Andersen, U.A. & Gamlem, L.P. (2005). *Acoustics in open-plan schools*. Report for the Master of Science at NTNU, faculty of Engineering and Technology, Trondheim 2005 (in Norwegian).
- [5] Vermeir, G. & Van den Bergh, J. (2003). *Classroom acoustics in Belgian schools: Requirements, analysis, design*. Second International Building Physics Conference, September 14-18. Leuven, Belgium.