Good acoustics for teaching and learning

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Summary
It is important that a classroom provide good speech intelligibility and good speak comfort. Being able to listen without effort is important for learning and teaching, and we know that poor room acoustics is a burden that impedes learning and affect teacher voice health. A very good learning place is the Swedish forests where we can communicate over long distances without having to raise our voice. I have made several listening tests in the forest and also measured the sound reflections in different forests. The results are interesting and I mean that “forest acoustics” should be the goal in terms of acoustic conditions in our schools. Many national sound standards put requirements on room acoustics in classrooms. One requirement is reverberation time, according to ISO 3382-2, and it´s often evaluated with $T_{20.}$ Unfortunately this is a very blunt measure, because we start T_{20} -evaluation first after the sound pressure level dropt 5 dB. This “waiting time” is often quite long and it´s a problem because we miss a lot of important information from the early part of the decay curve. A municipality in Sweden, Landskrona, wanted to improve the acoustics in their schools so they investigated the sound environment in their school buildings. In Sweden we have a sound standard, SS 25268, where we put requirement on the sound environment. Room acoustics is controlled by measuring reverberation time. In some classrooms in Landskrona the reverberation time fulfilled the requirements for good room acoustics according to SS 25268, but the teachers complained about “bad” room acoustics. One reason can be that the T_{20} measurement is only evaluated from the “late” part of the decay curve. By measuring Clarity C_{50} according to ISO 3382-1 we measure all sound reflections, and evaluate the balance between the “early” and “late” reflections. Therefore I mean we have to add C_{50} to control if the room acoustics is good enough for teaching.

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1. Introduction

Västervångskolan is a primary school in Landskrona, a city in southern Sweden. The school has 1000 students and about 50 classrooms. In one corridor with 5 classrooms teachers and students complained to the principal because the sound environment was bad. During the summer holiday 2013, 4 classrooms were renovated to improve the sound environment. But one classroom was not renovated.

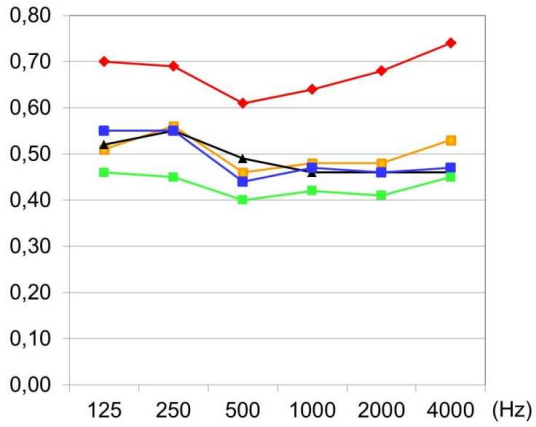
Classroom before renovation.

The reason why one classroom not was renovated was that people could walk between the renovated and not renovated rooms and listen to the different sound environments. When the school started in the autumn of 2013, teachers and students discovered that the sound environment was better. After one semester, the principal realized how an improved sound environment improved the student results. The teachers also felt it was "easier" to teach. See the movie on youtube where teachers, students and principals talk about the importance of sound in schools https://www.youtube.com/watch?v=rP-zwlbwoGo [1].

Before the classrooms were refurbished, some acoustic measurements were made according to the Swedish sound standard, SS 25268 [2]. The reverberation time, T_{20}, was measured according to EN-ISO 3382-2 [3]. and the noise level from the ventilation was measured according to EN-ISO 10052 [4]. The measurements showed that the noise level from the ventilation system fulfilled the requirements in SS 25268, both in dBA and dBC. But the reverberation time was too long.

To improve the working environment for students and teachers the municipality decided to replace the acoustic ceilings in the classrooms with a new type of ceiling and also install a wall absorber on the back wall

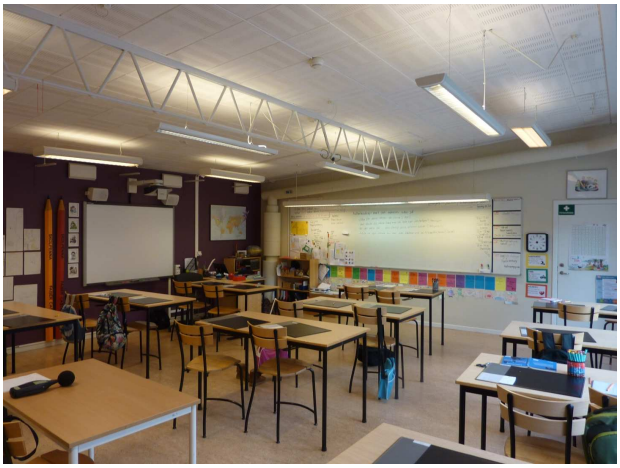
Classroom after renovation.



Reverberation time results.

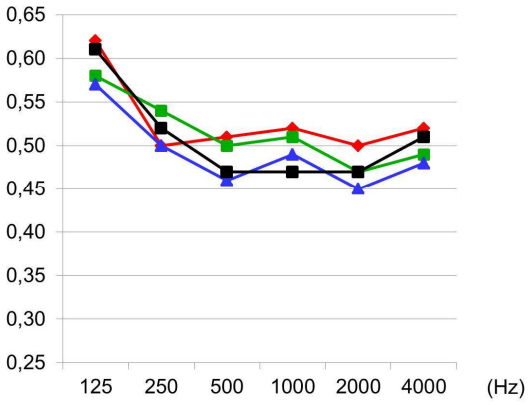
The red line shows the reverberation time in the untreated classroom. The other lines are the reverberation times in the 4 treated rooms. After the renovation the reverberation was shorter in all octave bands. The principals at the school informed the school managers in Landskrona about the positive impact the renovation had on teachers and students and during 2014 the local politicians decided to invest money to improve the sound environment in all schools in the municipality. Since both students and teachers were very satisfied after the renovation, the municipality-people who were responsible for the school buildings made the following conclusion: **If the reverberation time (RT) is short, the sound environment is good.**

The school politicians in Landskrona wanted to investigate how the sound environment were in their schools so the asked all principals to do a survey with their teachers. The teachers were asked what they thought about the sound environment in their classrooms. As you may understand, there were many schools reporting that the sound environment were bad, one of them was the primary school in Glumslöv.



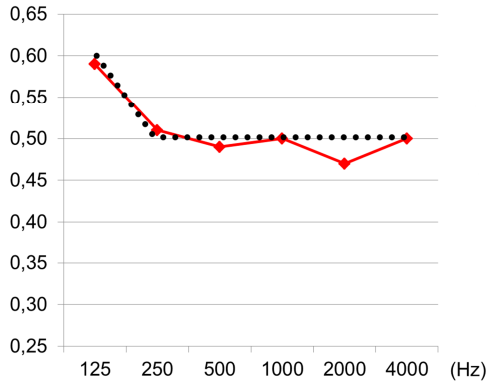
Classroom before renovation.

The school in Glumslöv consists of several smaller buildings and in one building there were 4 classrooms. Reverberation time measurements were made in the 4 rooms before the renovation.



RT in 4 classrooms before renovation.

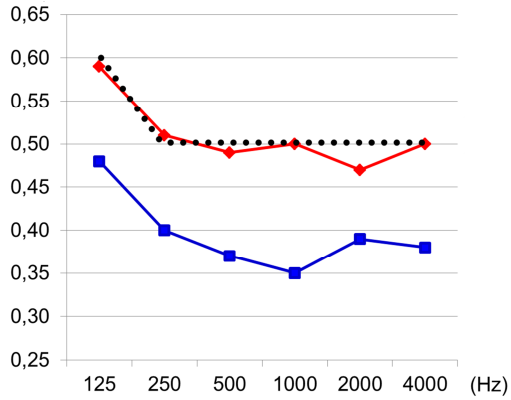
The interesting thing was that the reverberation times fulfilled the requirements for good room acoustics according to SS 25268, despite this, the teachers complained about a poor sound environment. The people at the municipality were puzzled because they thought if the reverberation time is short the sound environment is good.



Average RT in 4 classrooms.

The red line is the average RT in the 4 classrooms. The dotted line is the required RT for good room acoustics in classrooms according to the Swedish standard SS 25268. To improve the sound environment the classrooms were treated with a new acoustic ceiling and a wall absorber on the back wall.

Classroom after renovation.

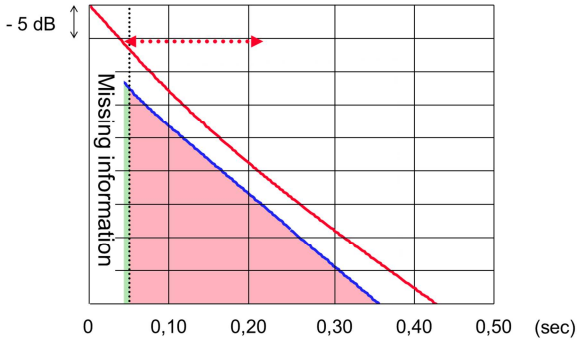


Red line is average RT in 4 rooms before renovation. Blue line is average RT in 4 rooms after renovation.

The people at the municipality were very puzzled by the fact that teachers complained although that the RT was ok according to the Swedish standard. This can be explained by looking at how RT is measured and evaluated.

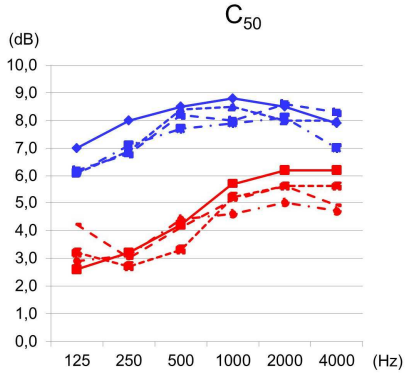
Reverberation time is a blunt measure

In the Swedish standard SS 25268, reverberation time is evaluated with T_{20}. Unfortunately this is a very blunt measure, because we start the T_{20} evaluation first after the sound pressure level dropt 5 decibels. I have done several measurements in different classrooms and discovered that classrooms with the same reverberation time can be experienced very differently. Comparing classrooms by measuring only T_{20} is not enough, because T_{20} do not include the early part of the decay.



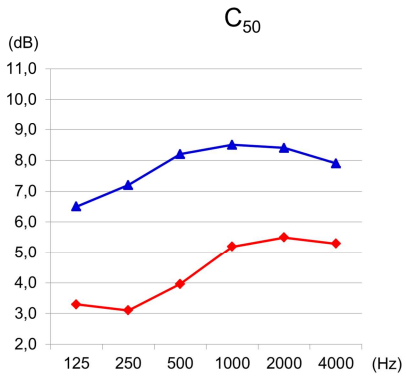
T_{20} do not include the early part of the decay.

The red dotted arrow shows the time then T_{20} is evaluated. As one can see we miss a lot of important information from the early part of the decay. In this example we miss about 40 ms. When you listen to a person who speaks in a room you hear the voice, and the reflections from the room. The early reflections, within 50 ms, support the voice and are positive for the speech intelligibility. Late reflections, after 50 ms, will decrease the speech intelligibility and makes it harder for the listener to understand that the speaker says. The early reflections are important for the speech intelligibility. Then we measure T_{20} we miss a lot of information from the early part of the decay since it takes some time for the SPL to drop 5 dB and this “waiting time” can sometimes be quite long, in some rooms up to 50ms. Since T_{20} don’t evaluate the early reflections in the room, it is a blunt measure, and therefore we have to add C_{50} according to ISO 3382-1 [5], to control if the room acoustics is good enough for teaching. By measuring C_{50} we will get information from all reflections in the room. C_{50} shows the balance between the early and late sound reflectors. Higher C_{50} value is better speech intelligibility.

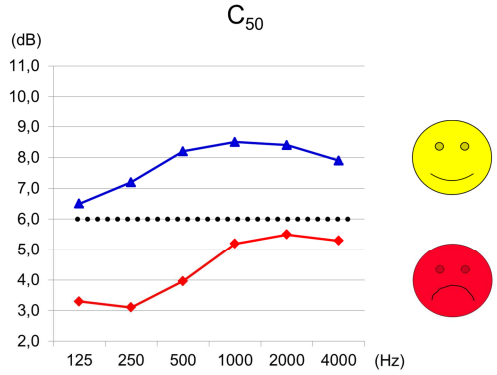


C_{50} results before and after renovation.

The 4 red lines are the C_{50} values in the classrooms before renovation. The 4 blue lines shows the C_{50} values after renovation.



Average C_{50} values for 4 rooms before and after.



The people at the municipality were puzzled by the fact that teachers complained on the sound environment although that the RT was short. Clarity, C_{50} shows the balance between the early and late sound reflectors. The average C_{50}-value of the 4 classrooms was about 4 dB before the renovation. After reconstruction C_{50} increased to about 8 dB. The teachers and students were

satisfied when the C_{50} was about 8 dB. But whey complained when C_{50} was about 4 dB. According to the Swedish standard SS 25268, the reverberation time was ok before the renovation. Before the renovation teachers and students complained about a bad sound environment. It is not enough to only measure reverberation time in a classroom to control if the room acoustics is good enough for teaching and learning.

2. Conclusions

Being able to listen without effort is important for good learning and we know that poor room acoustics is a burden that impedes learning. Therefor it's important that teaching spaces provide good speech intelligibility for listeners and also good speech comfort for the teachers. Many sound standards put requirement on class room acoustics with reverberation time, RT. The room acoustics is good if the RT is short. At the school in Glumslöv the teachers in 4 classrooms complained on the sound environment although that the RT was short. The average C_{50} value for the 4 classrooms was 4 dB before the renovation. After reconstruction C_{50} increased to 8 dB. The teachers and students were satisfied when the C_{50} was about 8 dB. But they complained when C_{50} was about 4 dB. Since RT misses a lot of information in the early part of the decay it is not enough to only measure RT in a classroom to control the room acoustics. C_{50} is a good indicator for speech intelligibility and my experience is when the C_{50}-value is 6 dB or higher (125-4000 Hz) teachers and students seems to be satisfied with the sound environment in their classrooms. Just measuring RT is not enough to control if the sound environment is good enough for teaching and learning. I mean that some national sound standards should add C_{50} as a requirement in room where speech intelligibility is important. Speech intelligibility is important in classrooms.

References

[1] A film about sound in schools from Västervångskolan in Landskona and Montessoriskolan in Båstad made by the National Agency for Special Needs Education and Schools, Specialpedagogiska Skolmyndigheten https://www.youtube.com/watch?v=rP-zwlbwoGo

[2] SS 25268:2007. Acoustics - Sound classification of spaces in buildings – Institutional premises, rooms for education, preschools and leisure-time centres, rooms for office work and hotels.

[3] ISO 3382-2:2008. Acoustics – Measurement of room acoustic parameters- Part 2: Reverberation time in ordinary rooms.

[4] ISO 10052:2004 Acoustics – Field measurement of service equipment sound - Survey method.

[5] ISO 3382-1:2009. Acoustics – Measurement of room acoustic parameters- Part 1: Performance spaces.