STUDIO ACUSTICUM
– A CONCERT HALL WITH VARIABLE VOLUME

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ABSTRACT

In the town of Piteå in the north of Sweden a new multipurpose concert hall, Studio Acusticum, was inaugurated in 2007. The acoustics of the hall is designed by Tunemalm Akustik with some help from Luleå University of Technology. Since Piteå is a town with a strong tradition of using wood for buildings, the construction consists mostly of wood. Surface treatment of the wooden elements permits good reflective properties. What makes this hall special is that the variable acoustics is accomplished by a height adjustable ceiling which can be raised or lowered 5 m, thereby effectively changing the reverberation volume by 30 %. There are also absorptive curtains which can be lowered to achieve short reverberation times for electronically amplified music. When compared to other multipurpose halls, this solution provides good acoustics for all uses without the need to compromise. A change in volume affects the reverberation time equally on all frequencies which gives better results than added absorption. Also, measurements have shown that reverberation time and clarity are the only parameters that change when the ceiling is lowered. Loudness, Lateral fraction and IACC are not affected by the change in ceiling height. This paper will give a thorough presentation of Studio Acusticum and its acoustical properties.

1 INTRODUCTION

What is a good concert hall? Which factors govern how the audience will perceive a concert? There are many factors, but the most important one is the *music*.

Different musical styles have different acoustical requirements on the hall. Throughout musical history, composers have adapted their works to the halls which were available. This fact makes music sound better, if it is performed in a hall which has acoustical properties characteristic of the time in which it was written. Composers like *Mozart* and *Haydn* sound better in smaller halls, while *Bach's* organ music sounds at its best in very reverberant halls. Certain music is even written with a specific hall in mind. *Wagner* wrote music specially adapted for the acoustics in Festspielhaus Bayreuth and *Bach* wrote music intended for the Thomaskirche in Leipzig. When designing a new concert hall, an acoustician must therefore optimize the hall according to what he knows or believes will be the primary usage. But what if you have the need to perform anything from organ music and symphonies to rock music and lectures? In that case, variable acoustics is the only way to go.

When planning started of the new concert hall in Piteå, Studio Acusticum, the demands from the Musical School of Piteå were that the hall should be able to accommodate ANY musical style. The acoustics also had to be “world-class”. So how do you achieve a no-compromise solution of variable acoustics? Electronic systems are good today, but they were not good enough for Studio Acusticum. Variable absorption is another way of doing it, but the problem is that absorption kills reflections and is not suitable for acoustical music with low reverberation requirements. The only option that could meet the high demands was a variable volume. Such a solution is a bit more complicated and expensive than the other options, but the results are undeniably the best.

Figure 1. The concert hall of Studio Acusticum

2 ACOUSTICAL DESIGN

The acoustics of Studio Acusticum was designed by Tunemalm Akustik in Umeå, with some help from Luleå University of Technology. The hall was inaugurated in 2007. The hall seats just above 600 persons and a bit more if a smaller stage configuration is used. The concert hall, see figure 1, is based on a classic shoebox design, with slightly angled walls. The town of Piteå has a strong tradition of using wood in building construction. Therefore, the concert hall is primarily a wooden construction. The inner surfaces have received a special treatment to achieve good reflective properties. The variable volume is realized by a height adjustable ceiling, which weighs 94 metric tons. To avoid structural movement because of the large mass, the ceiling is divided into five different sections which are only moved one at a time. The sections are suspended by synchronized chain hosts. Within minutes, the ceiling can be moved a vertical distance of 5 m, thereby changing the volume by about 30 %. In addition to the height adjustable ceiling, there are also absorptive curtains which can be lowered around the stage and side walls. These are to be used during electronically amplified concerts and speech. The surfaces of the walls are highly diffusive. The side walls are made of concrete, see figure 2. Above the stage there are curved reflectors to support the musicians. The stage is not raised, which made it possible to use a small incline of the audience, yet with good sightlines. Behind the choir platform is an open volume, which is reserved for a future organ installation.

Figure 2. Diffusive concrete and wooden walls

3 MEASUREMENTS

During the winter of 07/08, acoustical measurements were made in the concert hall. The following equipment was used:

- Elton omni-directional loudspeaker
- Norsonic measurement microphones
- MILAB VIP-50 variable polar pattern microphone
- Head Acoustics HMS III Dummy head
- WinMLS 2004 acoustic software

A logarithmic sine sweep with a length of 12 seconds was used. Three stage positions were used for the sound source, and twelve receiver positions were measured for each source position. Three different acoustical configurations were measured: High ceiling, low ceiling and low ceiling with curtains, see figure 3.

Figure 3. The three acoustical configurations which were measured.

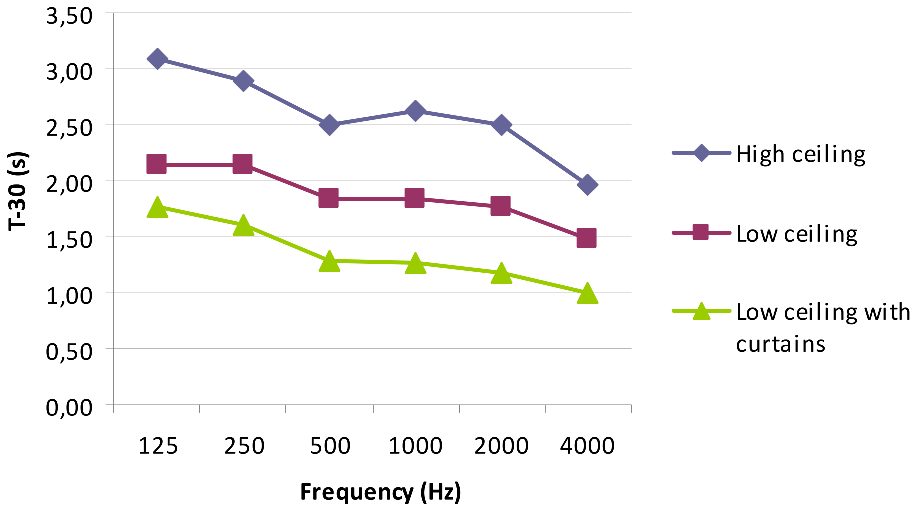

Figure 4. Reverberation time with different acoustical configurations

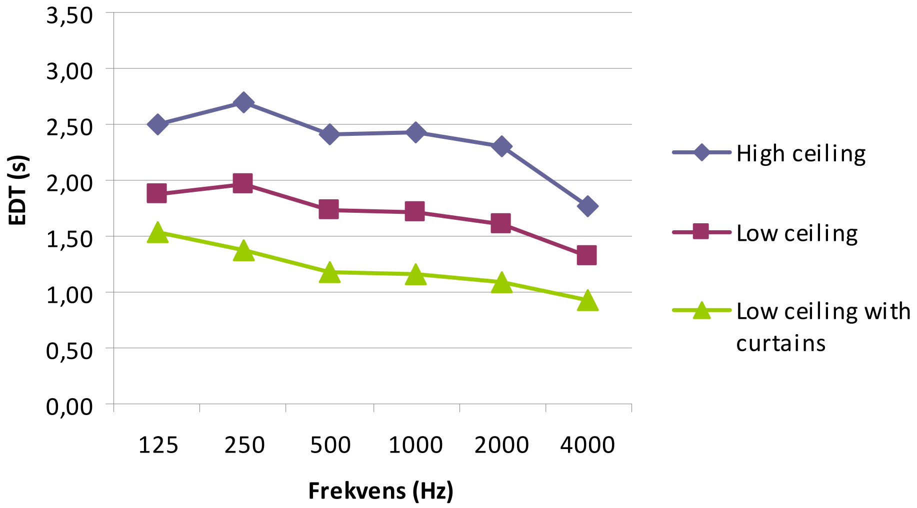

Figure 5. Early decay time with different acoustical configurations

The measurements of reverberation time and EDT in figure 4 and figure 5 show an advantage with the height adjustable ceiling. When the volume is changed, the reverberation curve is moved equally for all frequencies. This keeps the balance between frequencies the same. A variable absorption solution might affect higher frequencies more and “tilt” the curve. The curtains are apparently wisely chosen, since they work well even at low frequencies.

Other parameters which were measured are clarity (C_{80}), loudness (G_{mid}), early and late inter-aural cross correlation (1-$IACC_{E3}$ & 1-$IACC_{L3}$, 80 ms limit), lateral fraction (LF_{E4}) and lateral strength (LG_{mid}). The values are the average of the octave bands 500-2000 Hz (C_{80} and IACC), 500-1000 Hz (G_{mid} and LG_{mid}) and 125-1000 Hz (LF_{E4}). The results are given in table 1.

Acoustic configuration	C_{80} (dB)	G_{mid} (dB)	1-$IACC_{E3}$	1-$IACC_{L3}$	LF_{E4}	LG_{mid} (dB)
High ceiling	-1,2	9,0	0,58	0,88	0,42	4,0
Low ceiling	0,6	8,9	0,60	0,88	0,40	3,6
Low ceiling with curtains	3,0	6,5	0,51	0,82	0,29	-2,0

Table 1. The acoustical properties of Studio Acusticum

Clarity is dependant on the reverberation time and thus it is not surprising that it increases as the reverberation time decreases. Loudness is determined by absorption and volume. When the ceiling height is changed, the value of loudness remains the same. This indicates that the wall surfaces which are exposed when the ceiling is raised have very low absorption. The increase in reverberation time compensates the decrease in loudness due to the larger volume. When absorptive curtains are added, the loudness value drops.

An important factor regarding concert hall design is lateral sound. The lateral sound is especially important for acoustical music. It gives the listener a sense of envelopment, and a feeling that the sound source (the musicians) is wider than it really is. Early inter-aural cross correlation, lateral fraction and lateral strength are all measurements of the lateral sound in the hall. The volume change does not affect any of these parameters significantly. A change is only noticeable when the curtains are added. Late inter-aural cross correlation is a questionable measurement, since it gives similar values for almost all good concert halls[1]. It is believed to give an indication of the diffusiveness of the sound. A slight decrease is noticeable with curtains, which means that the sound field is less diffuse when absorption is added.

4 CONCLUSIONS

A multipurpose hall is usually designed using variable absorption. This can lead to problems when the need arises to lower the reverberation time during acoustic performances. These measurements have shown that the solution with a height adjustable ceiling works well. It permits a change in reverberation time and clarity without affecting loudness or lateral sound. When the curtains are used, the lateral sound is affected, but in those scenarios it is desirable. During amplified music or speech it is better to control the width and reverberation electronically in the PA system, to maintain clarity.

5 COMMENTS

The measurements of IACC are a bit high, compared to measurements of other halls. This might have been caused by the small size of this hall. In a small hall there are always reflective surfaces in the vicinity. It may also have been caused by “optimistic” measurement equipment. The most important thing to realize is that even though there might have been errors in the measurements, the equipment used was identical at all times. Should there exist an error, it will be constant throughout all measurements. We can still use the results to find relative differences between the different acoustical configurations.

6 REFERENCES

1. Leo Beranek, Concert halls and how they sound, New York : Acoustical Society of America, (1996).