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TWO NEW SOLUTIONS FOR ADJUSTABLE ACOUSTICS IN MULTI PURPOSE CONCERT HALLS

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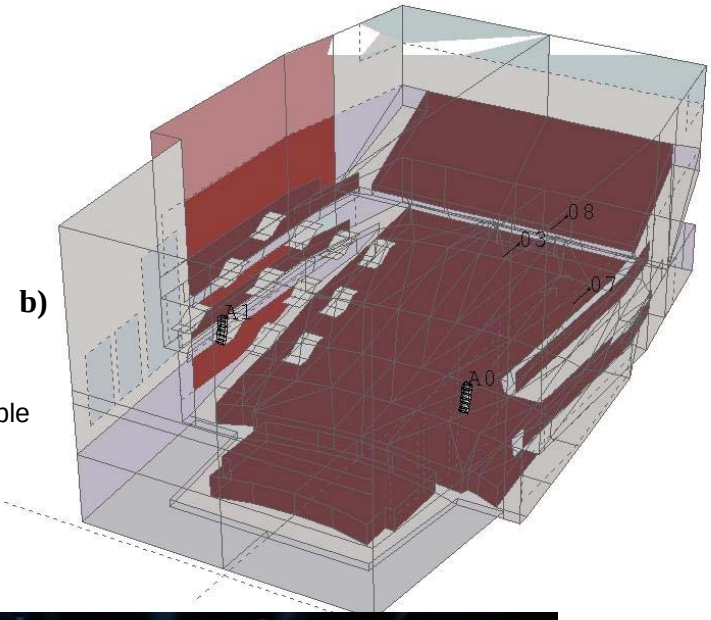
ABSTRACT
In the Swedish cities Lulea and Pitea two new multi purpose halls for classic concerts and amplified popular music, are being built. The sizes are around 650-950 seats. Both halls have been designed for adjustable reverberation time from 1,1 to 1,8 seconds. Two completely different solutions where chosen. The Lulea hall has a combination of solutions; adjustable wall absorbers, curtains and adjustable absorbing ceiling boxes. The new wall absorber construction is covering the side walls and comprises two panels with slots in front of each other and absorbers behind. One panel is driven by electric motors so that the slots are combined into openings or as closed panels. On the panels there are studs that act both as diffusors and as stiffeners to reduce low frequency losses. Measurements of absorption in lab and T_{60} in situ are presented, as well as analyses of the acoustic qualities. The Pitea hall is under construction and will have a completely different solution. The inner ceiling is constructed as five stiffened panels that can be lowered by a large number of chain hosts, thus reducing the reverberation volume by 30%.

BACKGROUND
Two new concert halls have been designed. Both of them have been acoustically projected and modelled by Tunemalm Akustik. The Pitea Hall has been designed by Monarken Architects and the Lulea House of Culture has been designed by Tirse´n & Aili Architects. Also, Lulea University of technology has been involved in some acoustical and construction matters. Both halls have been designed for a wide range of uses, from symphony orchestras to electrified music and conferences. The halls are designed to have space for 650 – 950 persons and reverberation times between approximately 1.1 to 1.8 seconds. The shape of the two halls is both nearly rectangular, with non parallel walls. Both halls where modelled with CATT Acoustics modelling software.

THE TWO DIFFERENT SOLUTIONS

The Lulea House of culture
The Lulea hall was inaugurated in January this year. The hall has room for up to 950 persons in the audience. The size is height < 17,5 m, w 22, length 33m. Volume approximately 10800 m^3. The main construction is in concrete and granite covered by wood panels. The inner surface is made of wood panels direct on concrete around the stage, wood panels on the sides and black concrete surface on the top part of the walls. Absorption can be added in steps by motor driven wall panels, fig 1 and 3, by drapes around the stage, by drapes on the top part of the side walls and by ceiling absorbers on hinges that can be opened, fig 2. The ceiling absorbers act as diffusers when closed. The drapes around the walls comprises two layers, one thin white drape at 300 mm from the wall and one black thick drape at 600 mm from the wall.

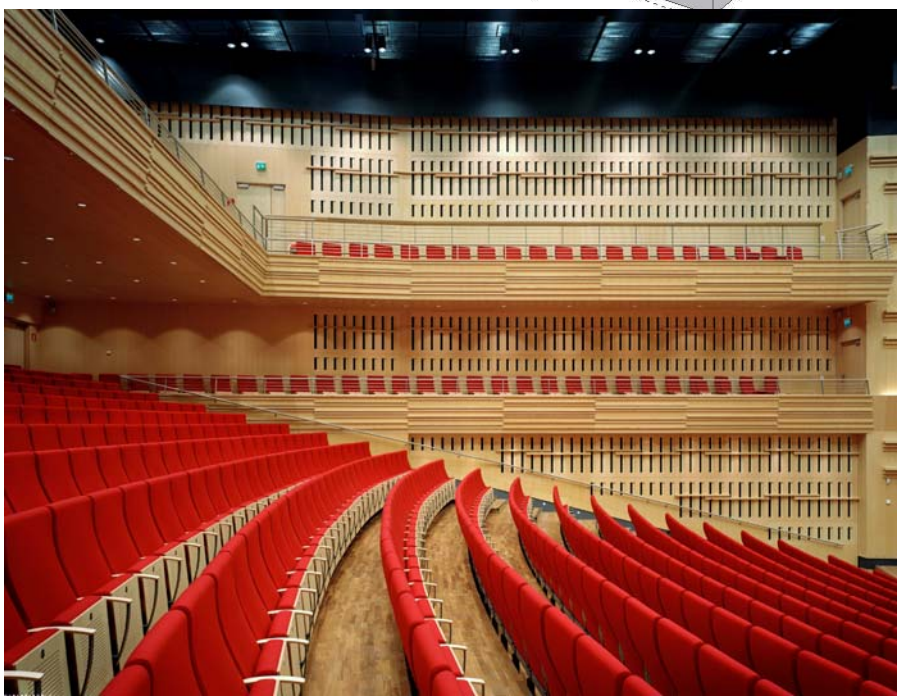
a)



b)

Figure 1. – Lulea House of culture

a) Exterior
b) CATT model
c) Interior side walls with adjustable wall panel absorbers. The wall panels are shown in opened condition. Black squares are mineral wool absorbers.



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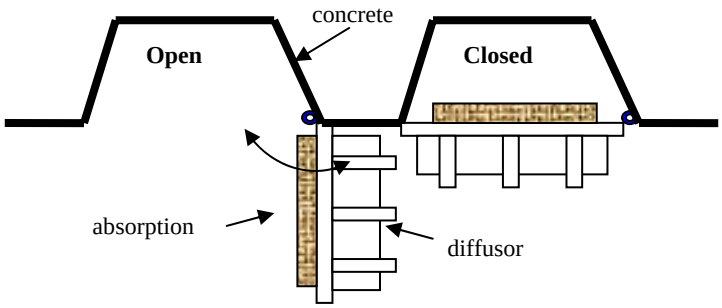

Figure 2. – Adjustable ceiling absorbers that are diffusive when closed and absorbing when opened, in Lulea House of culture.

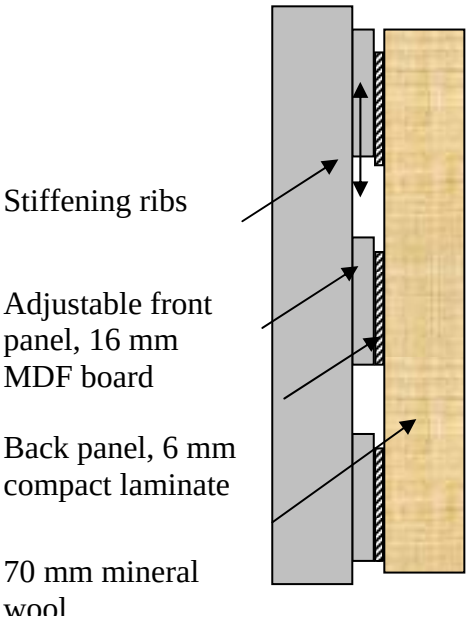

Figure 3. – Adjustable wall panels where the front panel is motor driven for adjustable opening to the absorber. Seen from above, Lulea House of culture.

The wall panels have remote control and may be continuously operated from open to closed position. When in open position the maximum exposed absorber surface is approximately 50 %. The stiffening rib is designed for stiffness and diffusion.

The Pitea Studio Acusticum

The Studio Acusticum will be inaugurated the 6th October this year and is a construction mainly in timber. The hall will have a total capacity of approximately 780 seats, floor area of 600 m^2 and volume of 9000 m^3. The inner ceiling comprises five 20m wide stiffened sections that can be adjusted from 10 to15 m height by 50 synchronised chain hoists. Thus changing the volume by about 1/3. The total ceiling construction has a weight of 94 tons. The chain hoists and control system is delivered by Unusual.Co. The choice of adjustable ceiling height is due to the assumption that a change in volume will give a linear reduction of the reverberation time by the same proportion in all frequencies according to the well known simplified Sabine Eyring expression (1). This expression though, is valid only for a diffuse sound field, for limited size rooms and for randomly distributed absorption, which is not the case at low frequencies, in large rooms and when the floor is heavily absorbing and the ceiling is reflective. In order to compensate for this, there are a number of diffusers added to the ceiling surface.

$$T = 0{,}16\frac{V}{-S \cdot 2{,}3\log(1-\bar{\alpha})} \qquad (1)$$

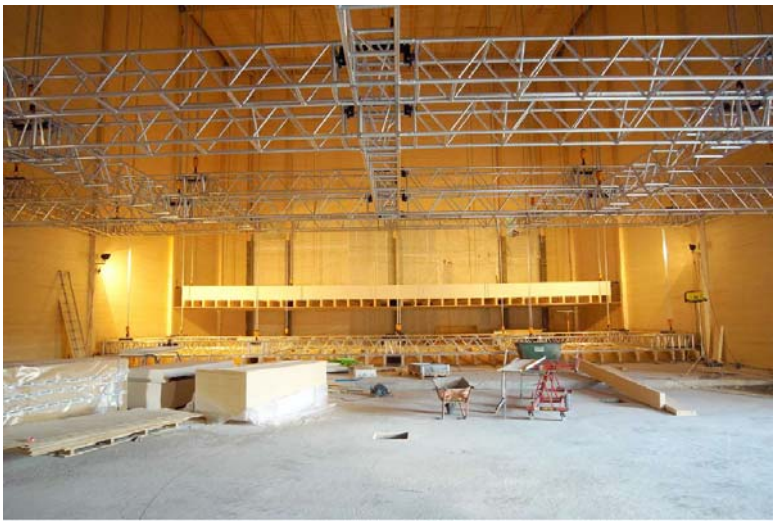

Figure 4.-A frame work (front) and a section (back) of the adjustable ceiling under construction.

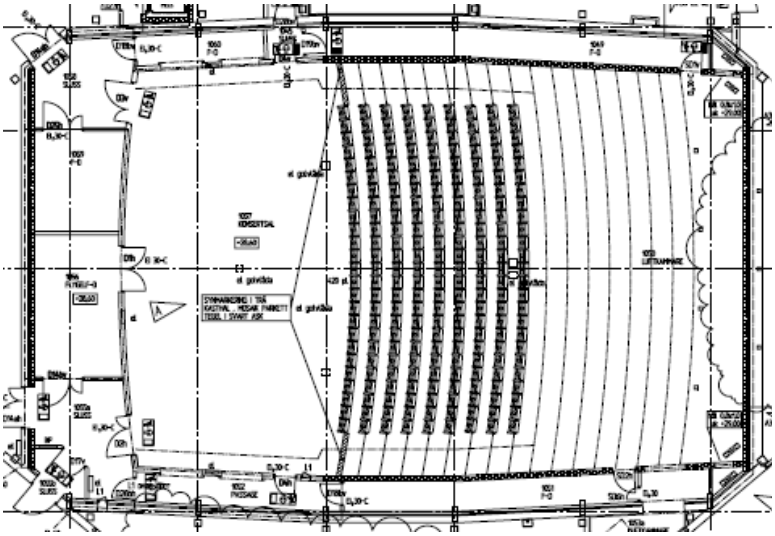

Figure 5.-The plan view of bottom floor of the Studio Acusticum. It is basically a rectangular room but with non-parallel walls.

MODELLING AND MEASUREMENTS

Both halls were modelled by Tunemalm Akustik in CATT, the objective was to reach a maximum average reverberation time of 1,8 seconds. The wall absorbers were measured by Lulea University of technology. The wall absorbers are built as two parallel supported panels of different size and material. There can therefore be expected to be panel as well as cavity absorption at low frequencies. To reduce the panel effect, stiffening ribs were attached to the panels, which also increased the diffusion of the panels. Laboratory measurements in a reverberation chamber gave the absorption coefficients in figure 6 below.

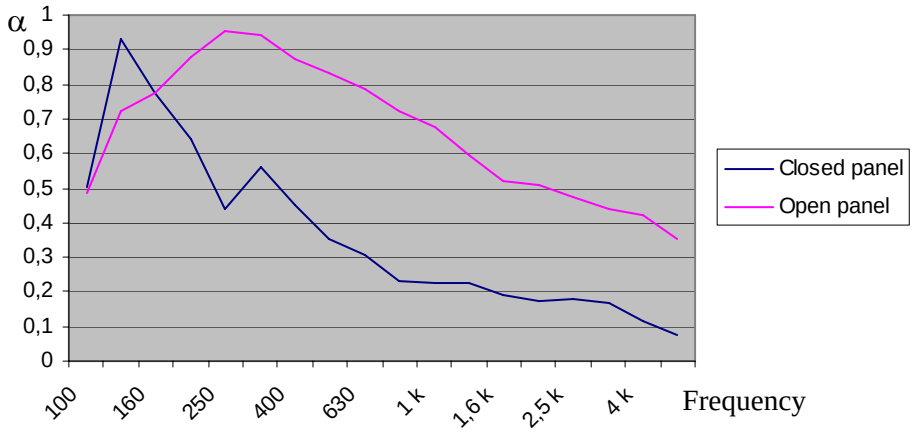

Figure 6.- Absorption coefficients of the adjustable panel absorbers in the Lulea hall, measured in a reverberant lab.

As can be seen in figure 6, the adjustability of the absorbers is about $\Delta\alpha$ = 0,5 in the frequency range 315 – 5kHz, where the effect of opening up for the resistive absorbers is seen. Probably there is panel absorption effects that can be seen at 125 Hz with the closed panel, while likely a cavity effect can be seen in the open absorber at around 315 Hz.

Reverberation time T_{60} was measured as an average of five positions. The average values can be seen in figure 7. Reverberation time was also measured in some additional positions. Further analyses will be carried out on initial decay, lateral reflections and reverberation variability. Typically it can seen that the reverberation at low frequencies is longer, which indicates that the building construction is rigid and reflective as was expected.

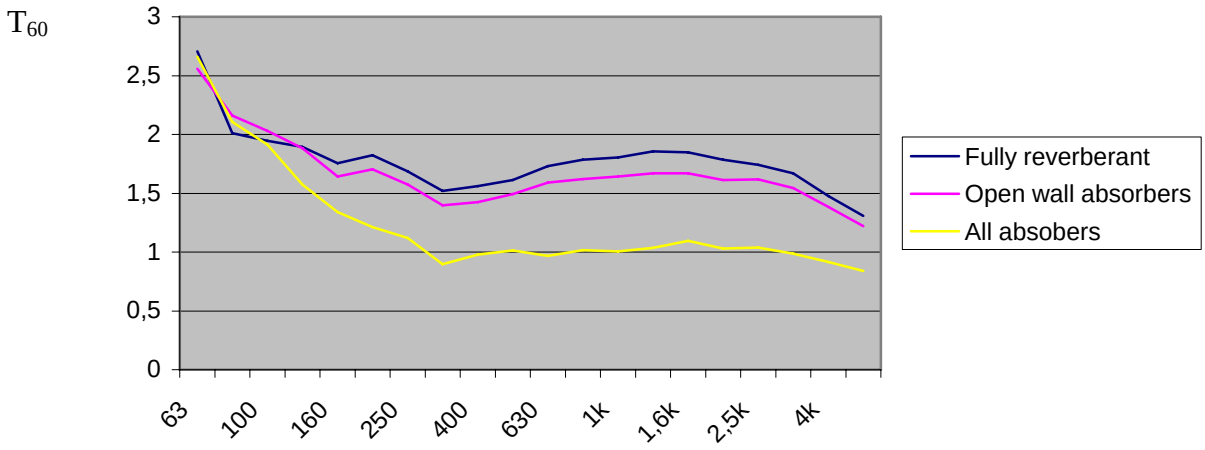

Figure 7.- Measured reverberation time T_{60} in Lulea House of culture hall.

MEASUREMENTS OF SOUND LEVEL DISTRIBUTION FROM THE PA SYSTEM

In order to evaluate how even the distribution from the installed PA system is at different seats, sound level mapping was done at 7 x 11 positions over the main floor and at some positions on the balconies. There was also an omni directional source put on the stage and the sound level reduction with distance was measured. All these measures were done to simulate electrified music and were therefore measured with maximum absorption. Measurements were done inat 1/3 octave bands from 20 to

20kHz.The PA system is a D&B system of (5p) Q1 , (1p) Q7 and (3p) Q-Base per channel.

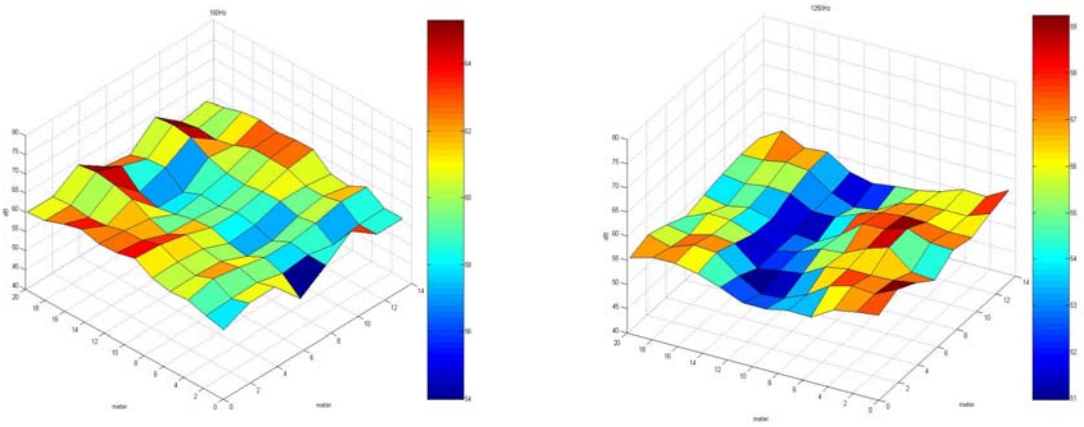

Figure 8.- Sound level maps in the fully absorbing hall with the installed PA system. Examples measured at 160 Hz (left) and 1250 Hz.

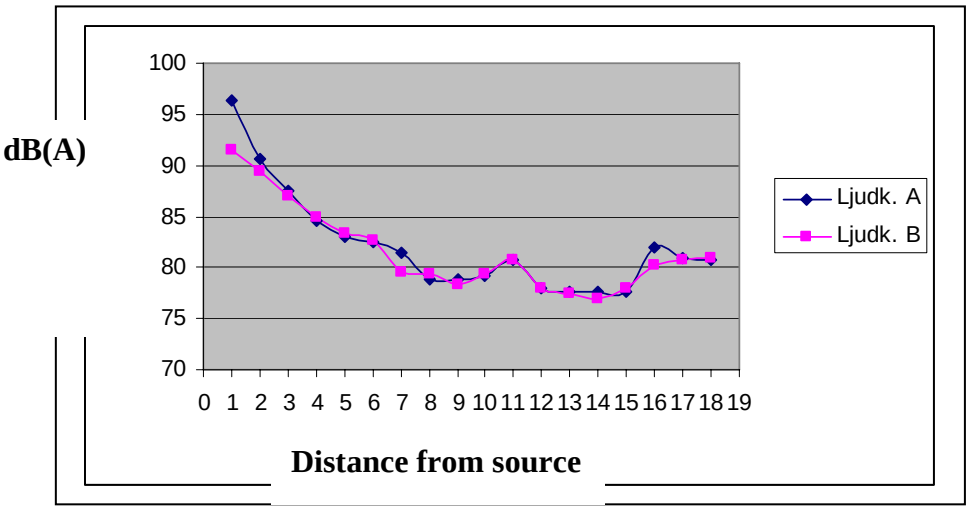

Figure 9.- Sound level as a function of distance from the source. Source position on front stage edge (A) and in the middle of the stage (B).

In the figure above it can be seen that the sound level is independent of source position on stage. This is probably due to stage wall reflections that compensate for the distance from the source.

CONCLUSIONS

Conclusions are so far only for the House of Culture Hall, as the Studio Acusticum Hall is under construction. The Culture hall has a combination of adjustable wall and ceiling absorbers and drapes, while the Acusticum hall has a ceiling that can be lowered in combination with drapes. The acoustic goals of the halls are approximately the same, a range of reverberation time between 1 and 1,8 seconds. This is well accomplished in the Lulea hall. The overall absorption contribution to the hall is a combination of all the absorbers. The effect of the wall panel absorbers was at 1 kHz a reduction from 1,8 to 1,6 s while the remaining measures gave further reductions down to 1 s. The Pitea Hall will be measured as soon as it is ready, hopefully results can be presented at the ICA conference.