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OPTIMIZING VARIABLE ACOUSTIC SURFACES

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Almost any performance space build today will have some sort of variable acoustic surfaces. These are used for changing the acoustics to better suit conference or reinforced music but also to a large extent to optimize the hall for the program played. Traditionally variable acoustics was mainly used in multipurpose halls and was typically implemented as changeable absorption surfaces placed on the sidewalls, either curtains or hinged elements. In the last 20-30 years, more extensive schemes of variable acoustics have been implemented also in dedicated symphonic halls. The most elaborate examples are the Artec designed coupled volume halls, such as Lahti or Lucerne. Also, several halls with variable volume (for instance a moving ceiling) have been implemented in the last 20 years. It is now typical to have for instance “rehearsal” curtains in concert halls. As for multi-purpose halls, the use of variable acoustic surfaces has developed from being just a “crude” control of reverberation to actual acoustic variability. This paper will investigate the effect of variable surfaces, both from the point of view of the placement of the surfaces as well as the acoustic characteristics of the surfaces. The data is partly for the series of measurements done by the author in Finnish concert halls in 2000-2003 and combined with measurements in recent halls.

Keywords: room acoustic, variable acoustics

1. Introduction

Even though a performance space (concert hall, theatre or opera house) is always somewhat “multipurpose”, real multipurpose halls have essentially been built from the 1930:ies onward. Especially in the 60:ies and 70:ies, building of multipurpose halls increased. However these halls were generally viewed as “compromise halls” or rather halls with compromise acoustic conditions. Obviously variable acoustic surfaces were used, such as stage curtains, but the first multipurpose halls with actual variable acoustics emerged around the 1980:ies. These were essentially theatre/concert hall/conference hall etc. combinations. In particular Artec and Russell Johnson began to implement the idea that even different kinds of acoustic performances should enjoy different acoustic conditions in the hall. In particular, with the design of coupled volume rooms, such as the Morton H. Meyerson Symphony Center in Dallas, USA and the Sibelius Hall in Lahti, Finland, variable acoustics was incorporated without compromising the acoustic quality for acoustic performances.

About half of the approximately 35 halls built in Finland between 1980 and 2000 have actual changeable acoustic surfaces, other than the stage curtains/changes on the stage. However, when investigating these halls, it can be seen that for the most parts these surfaces are not very efficient, in particular not at low frequencies.

It is well known that the acoustic requirements for acoustic, unamplified music are very different from the requirements for reinforced music. The main problem when playing reinforced music in a traditional concert hall intended for acoustic music is lack of control at bass frequencies, due to the longer reverberation time at these frequencies and the lower directivity of sound systems at these frequencies. The ideal reverberation time at 125 Hz for a 10000 m^3 hall (1000 seat) for reinforced is about 1,4 – 1,6 s [1] whereas the recommended reverberation time for acoustic music would be 2.0 – 2.2 s [2]. In other words, it is clear that functional multipurpose halls must have variable acoustics not only at high mid frequencies but also at low frequencies.

2. Materials used for variable acoustics

2.1 Mineral wool and similar

In the Finnish multipurpose halls, the typical variable acoustic surfaces are elements with mineral wool filling placed on the sidewalls. The idea is that when closed, the elements will function as “scattering/diffusing elements” and when open, as absorption.

Figure 1: Variable absorption elements (“Flip-Flops”) in the Topelius hall in Sibbo, Finland

The absorption characteristics of mineral wool is more or less 100% absorbing at high frequencies. The lower limit frequency for high absorption will be lowered by one octave when doubling the thickness of the material, from about 1000 Hz for 30 mm thick mineral wool, 500 Hz for 50 mm thick mineral wool to about 250 Hz for 100 mm thick mineral wool. Essentially the characteristics for high frequencies will remain the same. By adding a thin foil on top of the mineral wool, the surface can be made reflective at high frequencies and the resonance frequency of the plate will improve the characteristics at lower/mid frequencies.

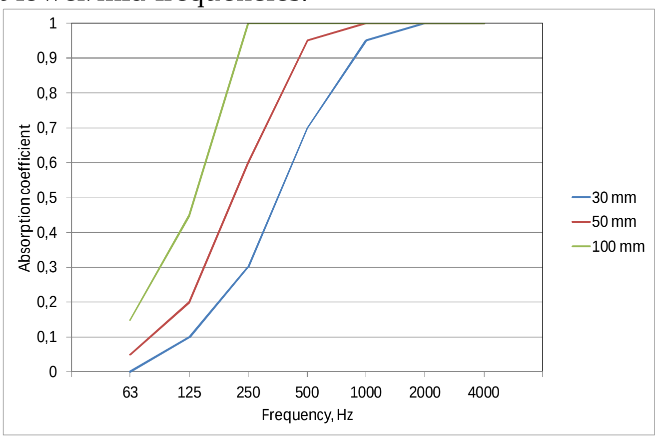


Figure 2: Typical absorption of soft surfaced mineral wool as a function of material thickness (Paroc Parafon Buller, data from producer)

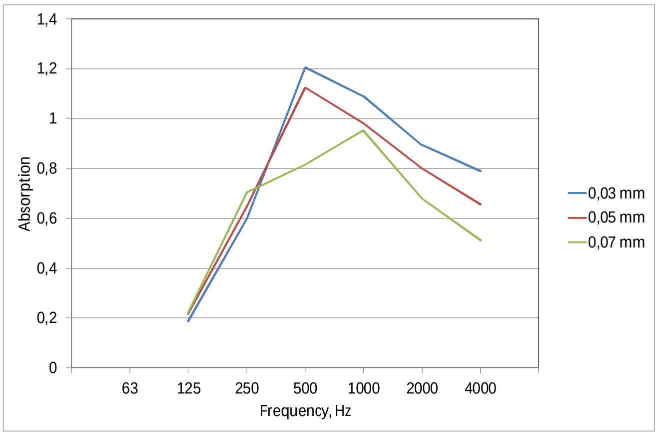


Figure 3: Change of absorption when a thin foil is added to the surface of the mineral wool [3]

2.2 Curtains

Curtains are extensively used in halls, both for stage curtains, for acoustics control and in many older halls as decorative elements.

From an acoustic point of view, traditional curtains behave like normal porous absorber surfaces, that is, they absorb high frequencies but not much low frequencies.

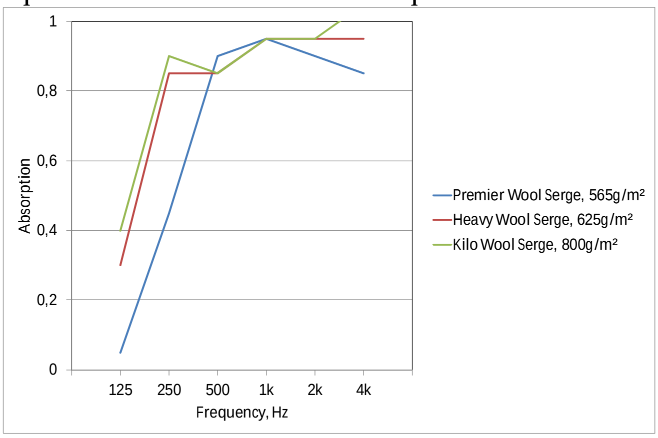


Figure 4: Wool Serge curtains of different weight (Data from J.C.Joel/SRL)

Figure 4 shows the absorption of a Wool Serge type curtains. Even though the data is for a specific manufacture, they can be seen as representative for Molton/Wool Serge types of non-backed fabrics. As can be seen, the connection between weight and absorption for simple curtain cloth is not linear. In other words, it would appear an increase in weight does not necessarily give an increased absorption at mid and low frequencies. The same seems to be the case for distance of the curtain from the wall. Increase in absorption is not a linear function of the increase of distance from the wall.

2.3 Bass absorbers

Traditionally, variable bass absorption has been very difficult to implement in halls. As shown above, all traditional materials used for variable acoustic surfaces will provide mainly high frequency absorption.

Bass absorption is normally achieved by either plates or different kinds of slotted or perforated structures. It is however difficult to change the absorption characteristics of these surfaces.

New materials from for instance FlexAcoustics provide an interesting new possibility for variable bass absorption [4].

One other option which is used for instance in the coupled volume halls is to open the doors to a volume with absorption. Experience from the Lahti halls indicates that this provides more or less frequency independent absorption.

Essentially the same idea is to use voids behind large slotted panels. When absorption, such as a roller banner, is applied in the void, this will provide low frequency absorption. This will also give some absorption at low frequencies even when the banner is removed, but this may not necessary be a problem in a smaller hall.

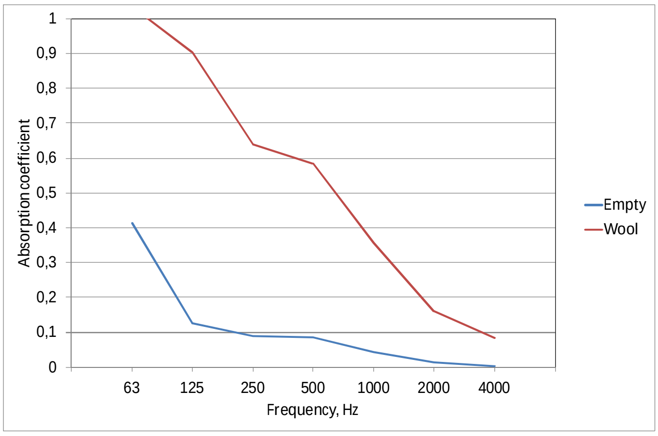


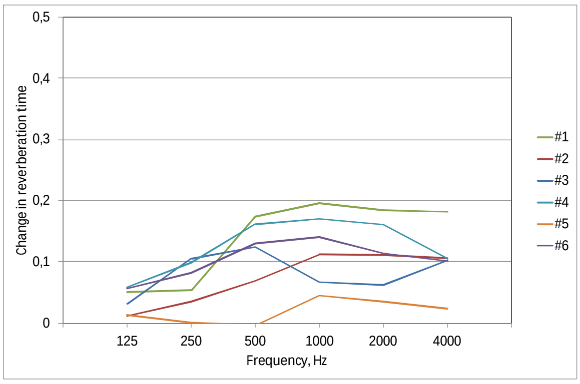
Figure 5: Theoretical calculations of a slotted panel (12 mm thick, 200 mm wide and 15 mm slots) in front of a 500 mm void, with and without 50 mm mineral wool in the void. (Data calculated with from Zorba v. 3.0.1)

3. Examples of halls with variable acoustics

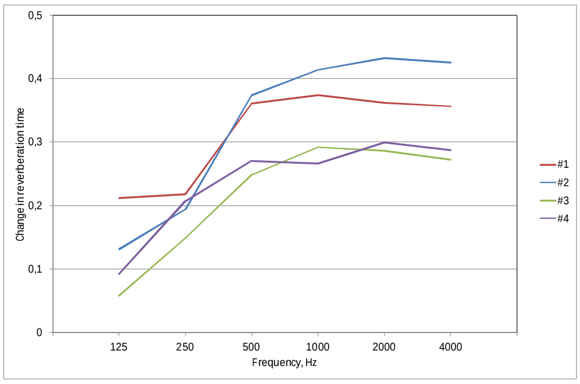
3.1 Halls from the 1980-2000 study

In a study done by the author between 1998 and 2001, 35 halls built between 1980 and 2000 were investigated [5]. Among the halls, 15 halls have actual variable acoustics, which are variable surfaces in the auditoria in addition to stage curtains.

Figure 6 shows the variation of the reverberation time in percent; in figure 6A just using the variable surfaces in the auditorium, in figure 6B both surfaces in the auditorium and stage curtains.



Just surfaces in the auditorium



Auditorium surfaces and stage curtains

Figure 6: Variability of reverberation time

As can be seen from figure 6, when using just the variable surfaces in the auditorium, the change in reverberation time is not dramatic. When also using the stage curtains, the change at mid- and high frequencies becomes larger, but the change at low frequencies is still not very significant.

In some of the halls above, the small change in reverberation time may be contribute to a low maximum reverberation time, in other words the amount of changeable absorption is not large compared to the overall amount of absorption in the hall. However some of the halls have quite long maximum reverberation time but even so the change is not large, and not sufficient to make the hall acoustically appropriate for reinforced music.

For most of the halls in the survey, the change of the Early Decay Time, EDT, when using stage curtains was larger than the change when just using the variable surfaces in the auditorium.

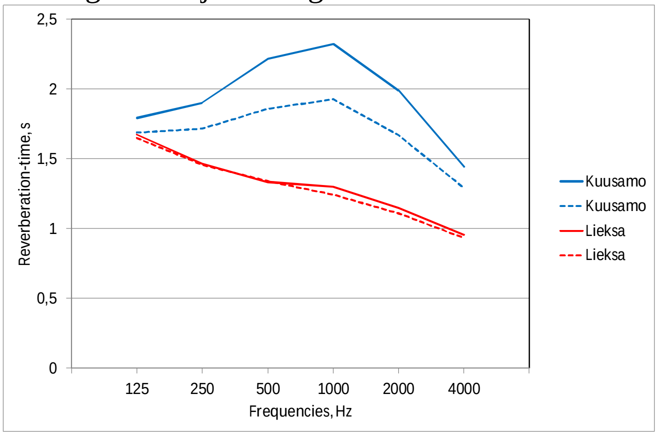


Figure 7: Reverberation time of the Kuusamo and the Lieksa hall, with (dotted line) and without added absorption in the auditorium

Both the halls shown in figure 7 have variable absorption implemented as hinged elements on the side walls. It is clear that in the Kuusamo hall, when the stage curtains are added, the reverberation time will be sufficiently short at mid and high frequencies, but the reverberation time at low frequencies will still be a problem for reinforced music.

3.2 Newer halls

Some newer halls have been designed with more extensive variable acoustic surfaces in the auditorium.

Figure 8 shows the measurement results from the Kauniainen “Nya Paviljongen” hall. This hall has mechanical curtains on all side walls as well as on the rear wall.

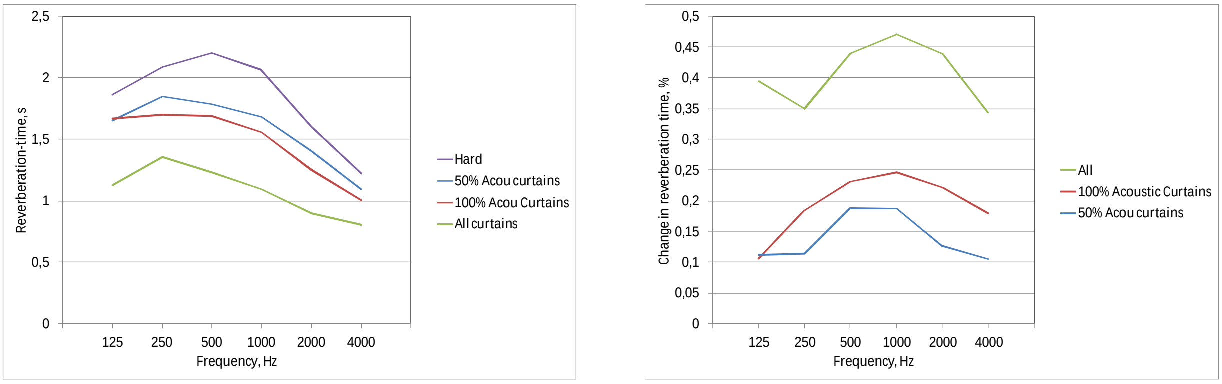


Figure 8: Reverberation time change and percentual change in the Nya Paviljongen hall

As can be seen, the change by the curtains in the auditorium is acceptable but not sufficient at low frequencies. However, when also the stage curtains are added, the reverberation time becomes acceptable for reinforced music.

Figure 9: Nya Paviljongen hall without curtains and with part of the curtains exposed

The Vanaja hall in the Verkatehdas Cultural Center in Hämeenlinna, Finland, is generally regarded as one of the best multipurpose halls for reinforced music in Finland. The hall was designed for reinforced music, conference, etc., but also to have acceptable acoustics for symphony music [7]. The hall has 4 double ceiling curtains, single roller curtains along the sidewalls and normal stage curtains. Furthermore, there is fixed absorption in the side and rear stage area, which become a part of the hall when the orchestra shell is removed.

Figure 10 shows the measured reverberation time and percentage change. As can be seen, the ceiling curtains are somewhat efficient at mid and high frequencies, but real changes in the reverberation time is achieved by changing the stage to soft (which implies removing the orchestra shell completely and adding curtains).

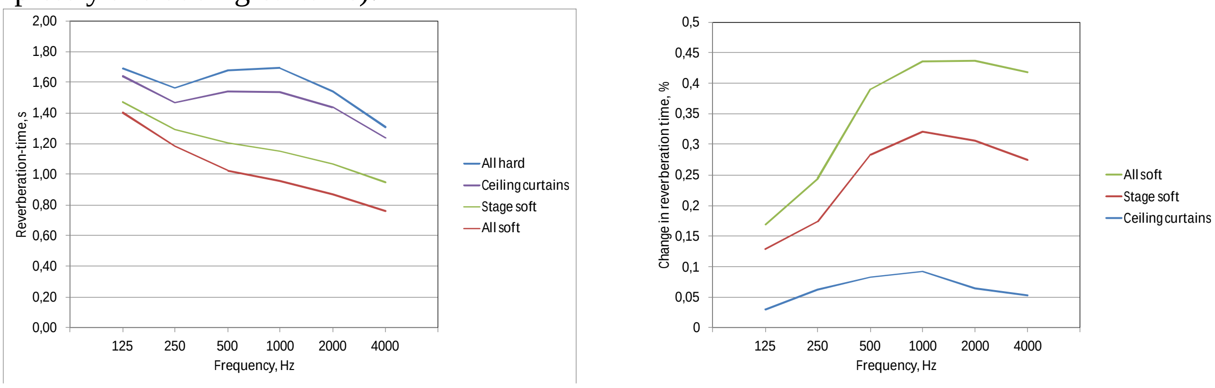


Figure 10: Reverberation time change and precentual change in the Vanaja hall

Figure 11: The Vanaja hall with orchestra shell

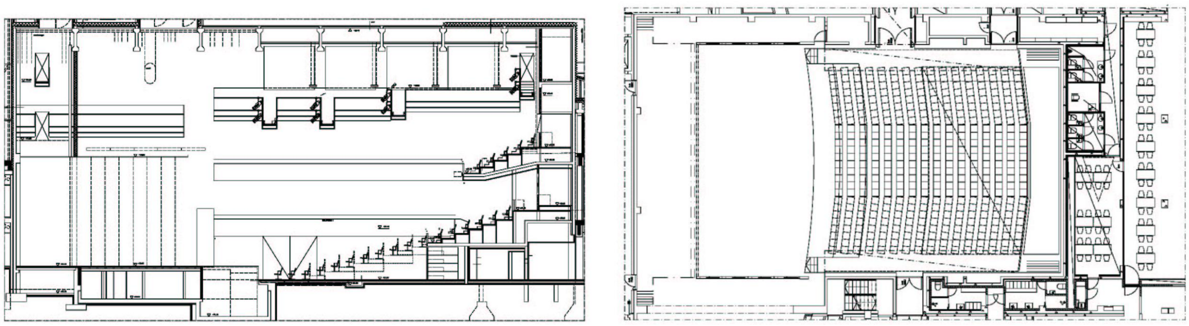


Figure 12: Section and plan (1st floor) of the Vanaja hall

4. Discussion.

It is clear that this investigation of the reverberation time, is only a simplification of the problem of variable acoustics. Most likely a better evaluation of the suitability of the halls for reinforced music could be done by evaluating EDT, Strength and Clarity parameters and in particular the parameters as a function of distance from the stage.

4.1 Effect of the added absorption in the auditorium

In general, the effect of the overall reverberation time of the curtains is somewhat small. Also for most halls the added absorption structures in the auditorium have little or no influence on the reverberation at low frequencies

4.2 Effect of stage curtains

From the measurements, it is clear that the stage curtains/stage structures are the structures that have the largest influence on the reverberation time in the hall. This inevitably poses a problem, as it means that the acoustic conditions on the stage and in the auditorium are very different.

4.3 Variability at bass frequencies

It seems very difficult to achieve real change at bass frequencies with traditional variable absorption surfaces (porous surfaces). However, one can also argue that in a 10 000 m^3 multipurpose hall (such as the Vanaja hall), a reduction of the reverberation time at low frequencies from 1,7 s to 1,4 s at 125 Hz is sufficient to make the hall suitable for reinforced music.

5. Conclusions

In this paper, smaller halls with variable acoustic surfaces have been presented. The investigation has been done only for reverberation time and shows that the traditional variable absorbing surfaces are not that efficient in the auditorium and that the surface in general, the surfaces do not work very well at low frequencies.

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