

# DESIGNING HALLS WITH VARIABLE ACOUSTICS

*Henrik Möller, Anssi Ruusuvuori, Olli Salmensaari and Oskar Lindfors*

Akukon Oy Consulting Engineers  
Kornetintie 4 A, 00380 Helsinki, Finland  
henrik.moller@akukon.fi

## ABSTRACT

In most cultural houses, extensive variable acoustics is essential to achieve good acoustic conditions for the different performances. The Vanaja Hall in the Verkatehdas Cultural Center is an example of such a space, with performance requirements from acoustic concerts, to reinforced music, theatre and even circus. The center was opened in August 2007. This paper will present a general view of different ways of achieving variable acoustics and present the specific solutions implemented in the Vanaja Hall. The measurements presented in this paper are part of the diploma work of Oskar Lindfors.

## 1. INTRODUCTION

Traditionally variable acoustics has been used in multipurpose halls to accommodate different uses, such as classical music and reinforced music and speech. In later years, also halls designed for “pure” classical or acoustic music has a large degree of variable acoustics. The idea behind this that different types of classical music requires different acoustic conditions; long reverberation time for romantic symphony works and shorter more intimate sound for chamber music etc.

The different schemes for variable acoustics can roughly be divided into two types:

- Variable absorption
- Variable volume

In the following, we will give a brief description of the different schemes.

### 1.1. Stage

It is clear that one of the most efficient ways of reducing the sound level in the space is by reducing it at source. In other words, an efficiently damped stage is essential for reinforced music. This is normally done by ensuring that there are heavy side drapes and back-drops on the stage.

### 1.2. Variable absorption

The first mentioned is the traditional way of achieving variable acoustics in halls. Absorbing surfaces are added or removed, typical curtains or “open-close” elements (so called “Flip-Flops”). This method has some problems:

- If curtains are used, it is necessary to use very heavy fabric to get absorption at low frequencies, and even so the performance at low frequencies are normally limited. The typical heavy fabric hung 200 mm from the wall surface will give absorption around 0,7 above 500 Hz, but less than 0,1 below 200 Hz. One of the advantages of using curtains is the ability to curtains coming down from the ceiling, thus effectively reducing the acoustic volume of room.
- When using “open-close” elements, it can be difficult to achieve sufficient large areas. Also these elements will obviously have to placed on the side walls and back wall, which is not necessarily the

most efficient placement. Also these elements will normally be somewhat more expensive than a curtain solution.

One new interesting method is to use “active” or inflatable bass absorbers, as made by Flex Acoustics. These elements achieve absorption coefficients of 0,4 to 0,6 around 100 Hz, which is very useful in multipurpose halls intended for reinforced music.

### 1.3. Variable volume

This is also referred to as “Coupled Volume” or as “Reverberation Chambers”. The basic idea is that by enlarging the volume of the hall, without adding absorption, the reverberation-time will increase, but as the geometry of the primary reflection surfaces can be kept static, the hall will have the same amount and spacing of early reflection and thus retain good clarity. There are principally two different ways of achieving this:

- Having an attached volume which is coupled to the main hall through doors etc. This concept has been used for instance in the halls in Lahti, Finland and Lucerne, Switzerland (Both halls designed by ARTEC).
- Actually changing the volume of the hall, typically by a movable ceiling. This concept has been used in the Sala São Paulo, São Paulo, Brazil (Design by ARTEC) and as is designed for the new concert hall for Stavanger Norway (Design by Kahle/Sinus/Akukon).

The main difficulty of this approach is actually achieving audible change. When using coupled volumes, for instance, it is indeed a challenge to get sufficient coupling between the spaces. In a shoebox hall with a 20 m by 40 m footprint, a change of 20% of the reverberation time requires the ceiling to move 3,5 – 4 m. So these schemes require quite large constructions and added building volume, and thus add considerably to the cost of the building.

## 2. THE VANAJA HALL IN VERKATEHDAS

The project was started by an architectural competition in 2003. In the architectural brief for the competition, a shoebox-style concert space with one or two side balconies was called for. The brief also called for a width of 17-19 m and a minimum height of 16 m., with full height in the whole space.

Use of the hall is as the list presented above, however the priorities were not as strict as normally seen. In this case it was decided that acoustics of the hall should be designed for a full orchestra as long as it did not jeopardize the other uses. It should be noted the city of Hämeenlinna only has a small city orchestra so the full size orchestra comes from a wish to accommodate visiting orchestras. In general the brief called for the “next generation” Finnish Cultural Center.

The architectural competition was won by JKMM Architects from Helsinki and the design was begun in 2004 and the complex was completed by June 2007.

From the design brief of approximately 750 seats plus the dimensions listed, an approximate room length of 35 m was estimated, along with the room having a maximum volume in the range of from 9,500 m<sup>3</sup> up to around 11,500 m<sup>3</sup>. This range was based upon the knowledge that a larger than normal volume would be needed to allow for attaining the balance between the Reverberation-time, T and the Strength, G, achieved, essentially, by a ceiling height approaching 18 m. Taking into account the existence of a rear balcony and two shallow side box balconies, the first calculations used  $V = 10,000 \text{ m}^3$  which for 750 seats is  $V_s = 13.3 \text{ m}^3/\text{seat}$ , normally considered to be a high value.

Another reason for using this volume was based upon the design philosophy of Kahle, a collaborator on this project, and the choice of a minimum volume depending upon the size of the largest acoustic performance, in

this case being a 100 musician orchestra. The theory applied here suggests a minimum volume of 100 m<sup>3</sup>/musician, where the assumption is that in smaller rooms, there would be at least 10 patrons/musician, and each patron would require a minimum of 10 m<sup>3</sup>.

## 2.1. Design Development and the Results of Computer Modeling

The winning entry from the architect competition had a basic shoebox layout, with a width of 17 m and 3 levels of side balconies. The design was investigated by computer modeling [ODEON] with the following principal results:

- The overall width of the hall should be increased to about 18 m, both for stage acoustic reasons but also for better balance of the early reflections.
- A two side balcony layout was acoustically favorable compared to a three level side balcony layout, because the height between the balconies could be increased, thus minimizing shadow effects and as the width was increased, more seating could be achieved. Also the modeling showed that the lateral efficiency and early reflection pattern would still be appropriate.
- The modeling clearly showed the need to acoustically narrow the hall near the ceiling.
- Some (variable) absorption would be necessary to reduce early reflections from the lower parts of the side wall for some circumstances.
- The model also indicated that it would be desirable to add (variable) absorption around the orchestra in some cases.

## 2.2. Description of the Vanaja hall

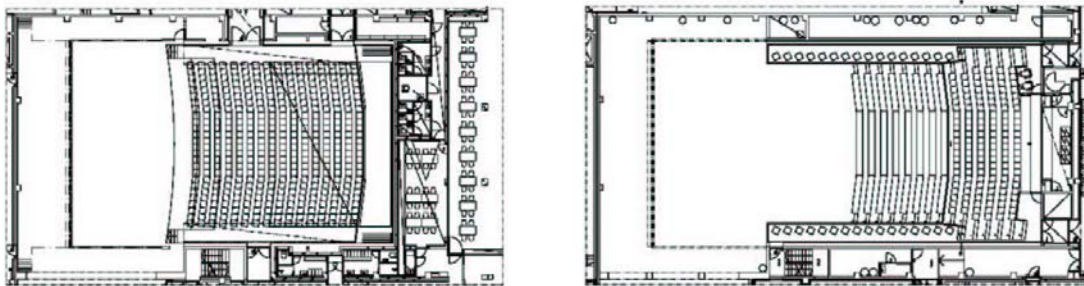


Figure 1. *Plans of the Vanaja Hall, first and second floor*

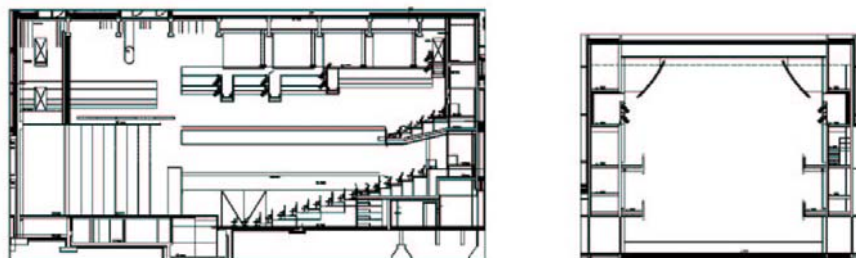


Figure 2. *Length and cross section of the Vanaja Hall*

The hall is basically a shoe-box with two side box balconies and rear-balcony. Furthermore there is a third technical balcony. The length of the hall is approx 34 m, the width 18 m and the height 18 m above front floor, (17 m above the stage). The stage is in normal setting 18 m wide and 9 m deep (162 m<sup>2</sup>) and can be extended

by a further 4 m into the audience. The orchestral pit is 4 m deep and 14 m wide and has a nominal depth 1.4 m below the front floor.

The seating consists of 416 on the main floor with movable risers, a fixed back floor with 140 seats, four side box balconies, with 16 seats on the lower and 17 seats on the upper balconies, and a rear upper balcony with 125 seats, yielding a total count of 715 seats.

The lower front floor riser can be configured to an extension for the upper floor seating, as is shown in the length section in Fig. 6, it can be configured to give a “half” rise with wider platforms for raised table seating, or it can be retracted to give a flat floor for banquets etc.

Both side and back wall are covered with “acoustic detailing” varying in depth from about 300 mm in the front of the hall to about 150 mm in the back.

The variable acoustics are implemented by curtains. The main curtains are four double curtains which extend from the ceiling 3 m down over the whole width of the hall. It is intended that these curtains will be the primary tools of adapting the acoustic of the hall to different performances as well as to add additional damping for rehearsals.

Furthermore there are curtains which can cover most of the side walls. These curtains are rolled down approx 200 mm in front of the wall surface and are retracted into the balcony construction when not used. The curtains will be individually operated, which for instance will make it possible to use the lower front curtains to reduce the strength of the first reflections of the orchestra.

The stage has a reflector cloud and areas with variable absorption, both on the stage side walls and back wall. Furthermore the side wall elements can be moved to “vent” the stage or in other words provide more absorption on the stage.

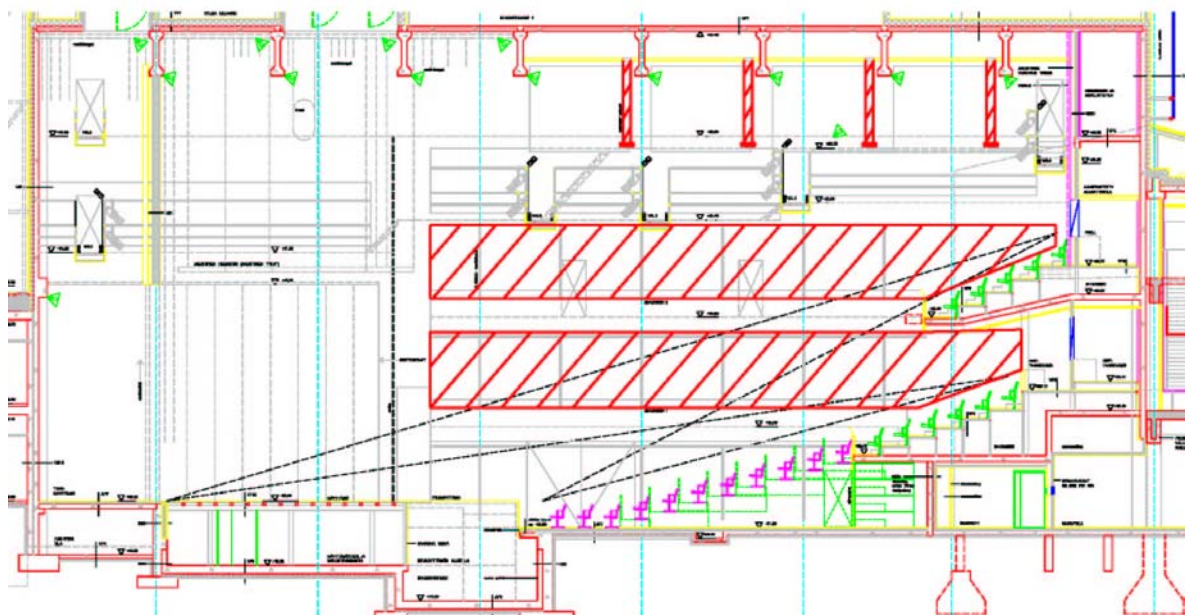


Figure 3. Placement of absorption curtains on side walls and transverse ceiling curtains



Figure 4. *Vanaja Hall, with The Rasmus on stage and curtains exposed.*

### 3. Measurement results and discussion

Over the previous year since opening, we have carried out an extensive series of measurements with the hall in different configurations. Figure 5 shows the measured reverberation-time in 4 different configurations. As can be seen from the figure and from the table below the maximum change of reverberation-time is about 40% for mid- and high frequencies and 15-20% for low frequencies.

Table 1:	<i>Change in Reverberation-time in percent</i>					
	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
From all hard to all soft	17 %	24 %	39 %	44 %	44 %	42 %
Stage from hard to soft	13 %	17 %	28 %	32 %	31 %	27 %
Just ceiling curtains	3 %	6 %	8 %	9 %	6 %	5 %

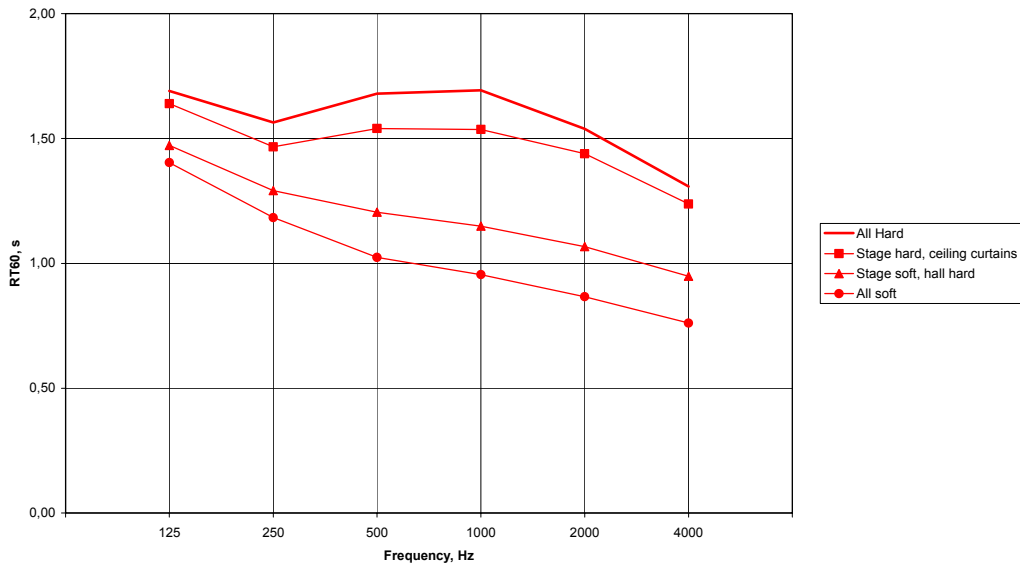


Figure 5. Measured reverberation-time with different configuration of variable acoustics

The results from the Vanaja Hall can be compared to a typical Finnish hall with traditional wall elements, the Sibelius Hall in Järvenpää (not to be confused with the Sibelius hall in Lahti!). This hall has approximately the same amount of variability with variable absorption elements covering most of the side wall and possibility to use side-curtains and backdrops on the stage.

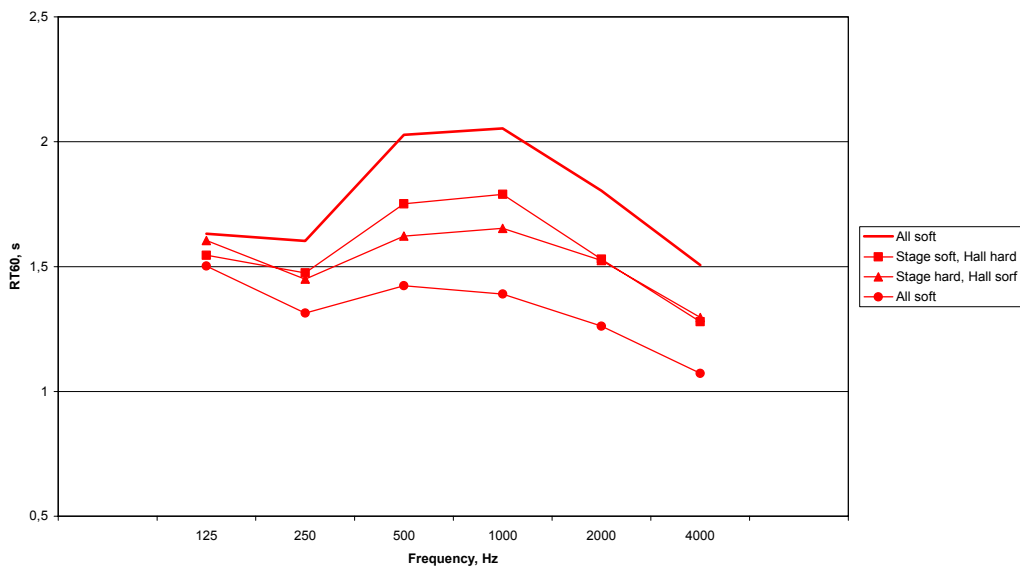


Figure 6. Measured reverberation-time in the Sibelius Hall in Järvenpää, with different configuration of variable acoustics

As can be seen, the reverberation-time at mid frequencies are quite long for a 570 seat multipurpose hall, but even so the relative change of the variable acoustics are only about 35% at the most. Perhaps interesting is that the relative change at low frequencies are only about half of what is achieved in the Vanaja Hall. One should also note that the variable structures in this hall are all manual, making acoustic changes quite slow.

#### 4. CONCLUSIONS

This paper has described the measures of variable acoustics implemented in the Vanaja Hall in the Verkatehdas cultural centre in Hämeenlinna and compared these results to the measurements of hall with traditional variable absorption wall elements. The comparison clearly shows that with variable absorption implemented with curtains achieves more efficient variability. These results are quite encouraging as the curtain system is the most cost efficient way of implanting easy usable variable acoustics.

In the future we will expand the investigation to also include halls with variable volume.

We would like to extend our thanks to the staff of both the Vanaja Hall and the Sibelius Hall for giving us the possibility to do the measurements.

#### 5. REFERENCES

- [1] Hyde J.R. and Möller H. "Sound Strength in small halls", *Proceedings of the Institute of Acoustics, Vol 28, PT.2* 2006
- [2] Möller, H., Ilomäki, T., Auvinen, J., and Ruusuvuori, A. "Verkatehdas hall, the new cultural center for Hämeenlinna Finland", *Proceedings of ISRA 2007*, Sevilla, 2007.
- [3] Möller, H., Lahti, T. and Ruusuvuori, A "Acoustical conditions of Finnish concert spaces", *Proc. B-NAM 2002, 26–28.8.2002*, Lyngby, 83–90.