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1 Summary

This paper describes acoustical computer modelling and designing of acoustical improvements of Turku Concert Hall. The project was carried out during the years 1998 - 2003. During the project, several acoustical measurements were carried out and over 20 different computer models were made to examine possible improvements of acoustical quality of the hall. The first stage of the improvements was realised in the spring of 2003. The paper will describe the project and present some of the results of computer modelling compared to on site measurements.

2 Turku Concert hall

Although built as late as 1952, Turku Concert hall is the oldest purpose built Concert hall in Finland. The hall is also one of the two Finnish concert halls, featured in Leo Beranek's pioneering study *Music, Acoustics & Architecture* (John Wiley & Sons 1962). The architect of the project was R.V. Luukkonen and acoustical consultant Paavo Arni.

In spite of certain acoustical problems, for example a disturbing back wall echo, the hall has had a good reputation among Finnish concert halls. The development of acoustical design and computer modelling and consequentially higher standards of acoustical design of recent concert hall projects in Finland, have however changed that view somewhat and the acoustical problems of Turku Concert hall have become evident.

3 The project

The one acoustical characteristic that needed urgent correction was the orchestras ability to hear each other. The first acoustical measurements in the concert hall were made in November 1998 and the results confirmed the orchestras opinion. After first negotiations it was decided that it is necessary to build an acoustical computer model to investigate the problem thoroughly. In the summer of 1999 the first investigations with the computer model were finished and the recommended solution was offered. The proposal included two rows of shelves added to the platform walls and some diffusive constructions on the platform back wall. The acoustical effect of the suggested constructions were tested with temporary structures in the spring of 2000 and the measuring results confirmed the positive changes. The actual building of the structures was however delayed by other renovations and changes in the planning group.

The project continued again in the late 2001, when it was concluded that the over all acoustics of the concert hall also needed improvement and further computer studies and measurements were commissioned. According to these studies it was theoretically possible to better the objective characteristics of the hall greatly without making permanent changes to the structures of the hall. The main problem in further design of these changes was however the fact that the hall is a well preserved example of the organic architecture of the 50's and any alterations of the plastered wall and ceiling, permanent or not, were bound to change greatly the hall's original visual concept. Around the platform area the alterations were luckily somewhat easier to make because of the rectangular wooden structures, and the first stage of the acoustical renovations were carried out in the Spring 2003 when two rows of glass shelves were added to the platform walls. Acoustical measurements were made once again and the results showed a considerable improvement of the room acoustic platform parameters. The reactions from the members of the orchestra have also been very favourable.



Figure 1. Turku Concert hall before alterations.



Figure 2. Computer model before alterations

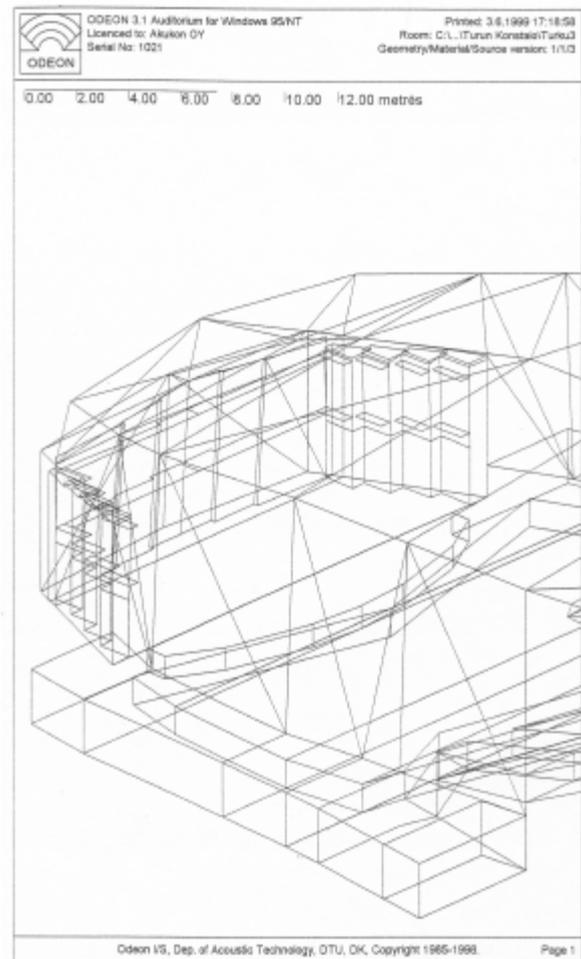


Figure 3. Computer model with glass shelves added to the platform walls.

4. Room acoustic platform parameters in computer modelling compared to on site measurements

In table 1 and 2 are presented some of the calculated and measured room acoustic platform parameters. In computer modelling the Odeon version 3.1 produced ST1 and ST total values. For the on site measurements ST2 value was calculated. As the values of ST2 and ST total vary only little, these parameters are considered to be comparable.

Table 1. Estimated values of computer modelling. 1, Concert hall before alterations. 2, Concert hall with glass shelves added to the platform walls.

| | ST 1 (dB) 250 - 2000 Hz | ST total (dB) 250 - 2000 Hz | CS (dB) 250 - 2000 Hz |
|----|-------------------------|-----------------------------|-----------------------|
| 1. | -17,01 | -13,42 | 16,5 |
| 2. | -13,96 | -11,82 | 16,3 |

Table 2. Values of on site acoustical measurements. 1, Concert hall before alterations. 2, Concert hall with glass shelves added to the platform walls.

| | ST 1 (dB) 250 - 2000 Hz | ST 2 (dB) 250 - 2000 Hz | CS (dB) 250 - 2000 Hz |
|----|-------------------------|-------------------------|-----------------------|
| 1. | -13,82 | -11,82 | 16,45 |
| 2. | -11,42 | -9,51 | 14,25 |

As we can see from the tables 1 and two, the expected ST1 and ST total values of the computer modelling are much more pessimistic than the actual measurement values. The amount of change in the ST1 and ST 2 values is however very close to predicted.

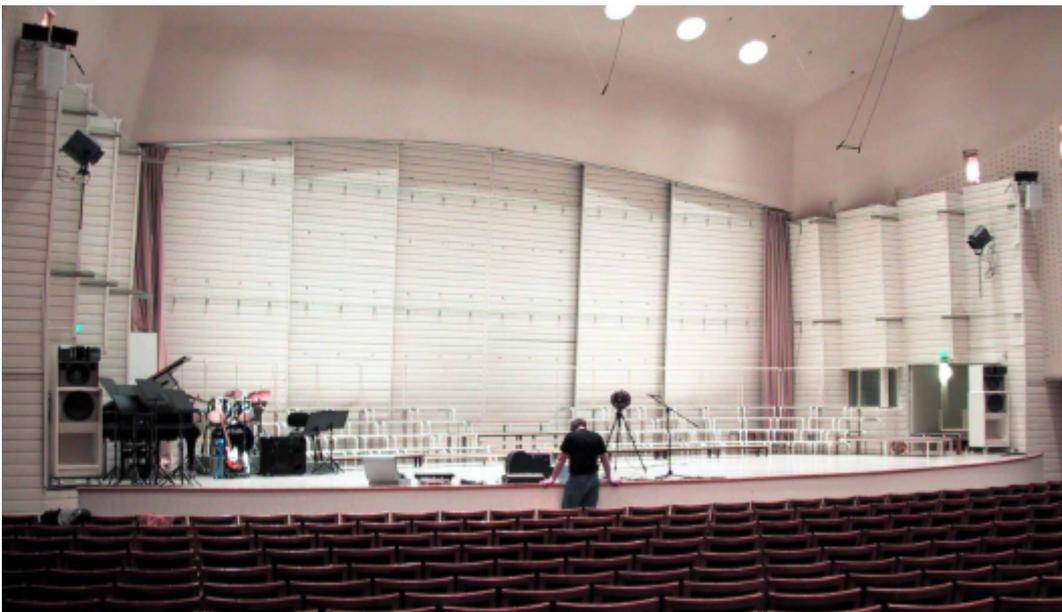


Figure 4. Acoustical measurement after installation of the platform shelves.

5. Conclusions

At the time, when the Odeon 3.1 calculations were made, the platform parameters, like ST1 and ST total were new additions to acoustical computer modelling and there was little previous data to determine how accurate the estimated results would be. During the project we found the expected values to be more pessimistic than those of actual measurements. The most important factor of this project was however the amount of change that could be achieved with suggested structures and that was very accurately estimated by the computer program.

Especially in this kind of project, where any addition to the original architecture is hard to push through, the acoustical computer modelling proved to be an irreplaceable tool. Although the structures that were installed in the hall were fairly simple, and basically similar to those that were suggested even before any computer modelling, it is doubtful that any of

these structures would have been realised unless there was a clear data of the estimated acoustical changes. With the computer model it was also very useful to examine the limits of acoustical improvements that is possible to introduce to the hall.

Whether there will be any more acoustical changes in the hall remains to be seen. The contradiction between acoustical and architectural demands is not easy to solve, but at least one of the acoustical problems of Turku Concert hall has now found an agreeable solution.

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