SIMULATION MODEL ASSESSMENT OF A SOUND INSULATING DOUBLE FAÇADE SYSTEM WITH OPENINGS FOR NATURAL VENTILATION UNDER GUIDANCE OF LABORATORY MEASUREMENTS

ONURCAN ÇAKIR[1]
JOSEF LECHLEITNER[2]
ARDESHIR MAHDAVI[3]

ABSTRACT

Noise control and natural ventilation are two main building physics issues which have contradictory principles. While natural ventilation needs openings on the façade in order to let fresh air in, the desired acoustic insulation is provided with minimum openings or without any opening on the wall. This paper presents a comparison between the simulation model results and laboratory measurements of a double façade system which is proposed in order to minimize outdoor noise coming through façade openings in naturally ventilated buildings. The double façade with twenty five openable equal-size particleboard panels on each side was constructed as a full scale model in the laboratory and the same setup was modeled in a computer simulation program. Different parts from these two parallel walls were taken out and the effect of the distance between these openings on the sound reduction value of the system has been analyzed. After the measurements; materials, their sound absorption coefficients and the reverberation times of two rooms were calibrated in the simulation program accordingly and simulations were run in order to check if it would be possible to continue this research only with computer models. The results are compared and differences between the simulation and laboratory measurements are stated in this paper.

Keywords: Noise control, natural ventilation, acoustics, sound insulation, simulation.

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[1] Res. Assist., Izmir Institute of Technology, Departement of Architecture, IZMIR
[2] Tech., Vienna University of Technology, Department of Building Physics and Building Ecology, VIENNA
[3] Prof. Dr., Vienna University of Technology, Department of Building Physics and Building Ecology, VIENNA

1. INTRODUCTION

Ecologic approaches lead architects to behave more carefully about protecting natural resources and therefore to design energy efficient buildings. Technology brought houses many comforts mostly by using extra energy. Thus, conventional physical environment methods came out to solve this problem, but with modern materials and techniques. Natural ventilation is one of the ecological solutions for indoor air quality which has also economic benefits since no additional active systems will be necessary. However, natural ventilation and sound insulation have contradictory principles because natural ventilation requires openings on buildings' facades while openings reduce the acoustic insulation rate of the facade.
Inhabitants are mostly annoyed by road traffic as noise source and people are unsatisfied with their neighborhoods mostly because of noise problems (Kuerer 1997). There are different ways to attenuate sound during natural ventilation. Acoustic louvres, elevated screens, balconies, courtyards and porous duct linings can be used for attenuating mid to high frequencies; quarter wave resonators and Helmholz resonators for low to mid frequencies; panel resonators and active noise control for low frequencies; and closable apertures for all frequencies (De Salis et al. 2002). Former studies show that the expected sound insulation performance of an open window is approximately between 10-15 dB according to international and regional standards (Nunes et al. 2010). The scientific report of Napier University provides results of a series of measurements done with seven window models and with a total of twelve different opening types (Napier University 2010). Open window sound transmission is assumed to be through a 0,05 m^2 opening and the measured Dw results are between 14 and 20 dB. It is also found that increasing the open area on the façade reduces the level of acoustic insulation. The glazing specifications and frame materials did not affect the sound attenuation of open windows.
Taking former research into consideration, a modular double façade system is designed in order to have natural ventilation and acoustic control at the same time (Mahdavi et al. 2012). That study introduced the laboratory measurement values as base for this present paper. During the design stage of this flexible structure, the sound phenomena 'diffraction effect of barriers', 'sound absorption by reflection' and 'the attenuation due to distance' are taken into consideration. In this system, two particle board walls are designed which are carried by an aluminium structure. Each wall consists of twenty five removable parts, which can be considered as windows of the façade system. By arranging the openable windows vertically reverse situated on the inner and outer side of the double facade, direct sound paths from the lower side (e.g. traffic road) will be prevented geometrically. Similarly, using a shifted irregular aperture arrangement on the inside and outside in the horizontal direction will provide sound attenuation due to the diffraction effect of closed parts. Figure 1 represents the main principles of this system on a schematic plan diagram.

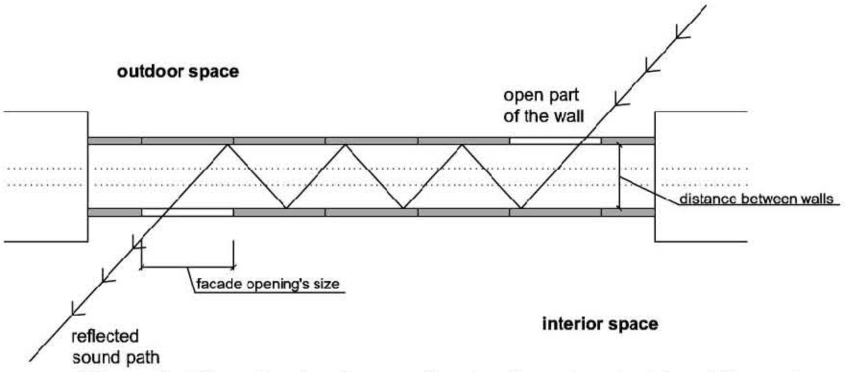

Figure 1: Schematic plan diagram showing the main principles of the system.

In order to test the performance of this structure, laboratory measurements and computer models are carried out. Laboratory measurements and simulation model calculation results from the computer program Odeon are compared and analyzed in order to check the reliability and conformity of the simulation program to continue the study without measurements.

2. COMPUTER SIMULATION MODEL

2.1. Room Setup

Acoustic measurements are done in the Building Science and Technology Laboratory of Vienna University of Technology. A grid aluminium frame structure is designed for building up a double facade model in the opening between two rooms in the laboratory. The opening is 3,08 m high and 3,08 m wide. The distance between two walls of the proposed double façade model is 35 cm. Each wall of the double façade has a fixed frame part outside with the width of 29 cm. The five to five grid structure inside this frame consists of square divisions with the dimensions 50 x 50 cm. In order to define all parts of the grid clearly, each element is given a certain number on each side of the double façade as it can be seen from Figure 2.

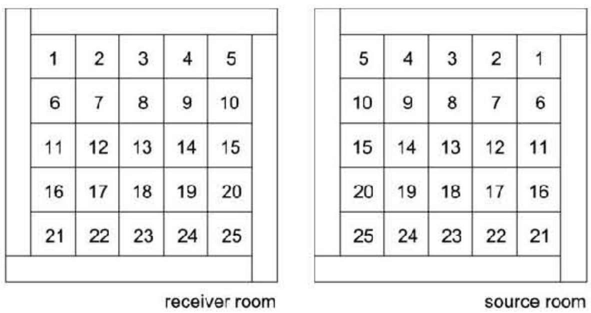

Figure 2: Numbering the removable grid parts of both walls.

A computer model with the same room dimensions and settings is prepared in order to check the possibility to get near results to the laboratory measurements. A 'dxf' file of the model, which can be seen on Figure 3, is created with layers according to materials and this file is imported into the program 'Odeon version 9.2'.

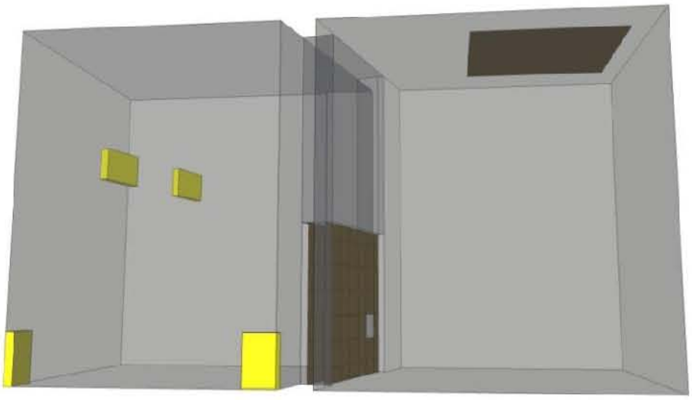

Figure 3. Source and receiver rooms in the simulation.

Two source positions and five receiver positions for each source point according to the standard ISO 10140-4 are determined as shown in the Figure 4 (ISO 2010).

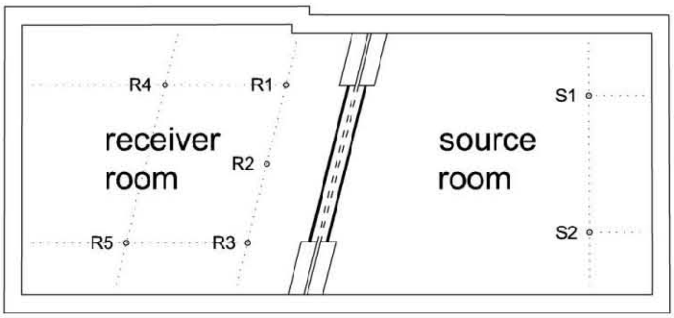

Figure 4. Plan of the source and receiver positions both in laboratory and simulations.

2.2. Calibration

In order to make a reasonable decision about the sound absorption coefficients (α) of each material in the room, the reverberation times according to laboratory measurements and the Odeon simulation results have been calibrated. Table 1 shows the α values which are used for the computer simulations.

Table 1. Absorption coefficient values which are used in computer simulations.

Absorption coef. (α)	**125**	**250**	**500**	**1000**	**2000**	**4000**
Concrete (for walls)	0,02	0,03	0,04	0,04	0,04	0,04
Rockwool	0,53	0,98	0,98	0,97	0,97	0,97
Particle board (sanded)	0,04	0,04	0,06	0,06	0,04	0,04

In the receiver room, rockwool plates are placed in order to have reasonable reverberation time values. With the aid of properly selected materials, a great agreement is reached between the laboratory measured reverberation times and simulated values as seen in Table 2. Experiment walls in Odeon are defined as 'transmission walls' which allow sound transmission according to their R values for each one-third octave frequency.

Table 2: Reverberation time comparisons of lab. measurements and Odeon results.

Reverberation Time [s]	**125**	**250**	**500**	**1000**	**2000**	**4000**
Receiver Room - Odeon	3,65	2,84	2,22	2,14	1,96	1,52
Receiver Room - Lab.	3,80	2,63	2,37	2,48	2,16	1,50

3. RESULTS

The cases 'one closed wall' and 'two closed walls' are examined firstly. The comparison between the sound reduction values for the façade structure derived from Odeon simulation models and laboratory measurements are given in the Figure 5.

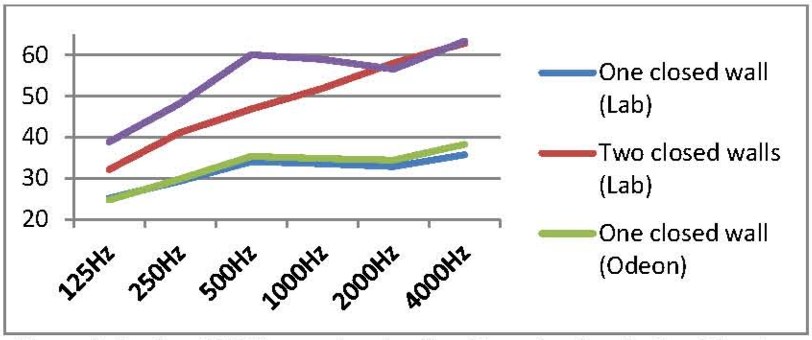

Figure 5. R values [dB] for one closed wall and two closed walls from laboratory measurements and Odeon simulation program.

In the case 'one closed wall', simulation and laboratory measurement results tend to be quite similar to each other even though they have some small differences. In the case 'two closed walls', Odeon overestimates the sound level difference between the rooms at lower frequencies between 125 and 1000 Hz, where it slightly

underestimates at high frequencies like 2000 and 4000 Hz. Especially at 500 Hz there is a major difference between laboratory and Odeon results.
Secondly, the removable grid element with the number '6' on the receiver room side is kept constantly open. On the source room side, the elements '16-17-18-19-20' are erased in the simulation one by one and calculations are done. The graphical comparison of the cases with one opening on each wall according to Odeon simulation results is shown in the Figure 6.

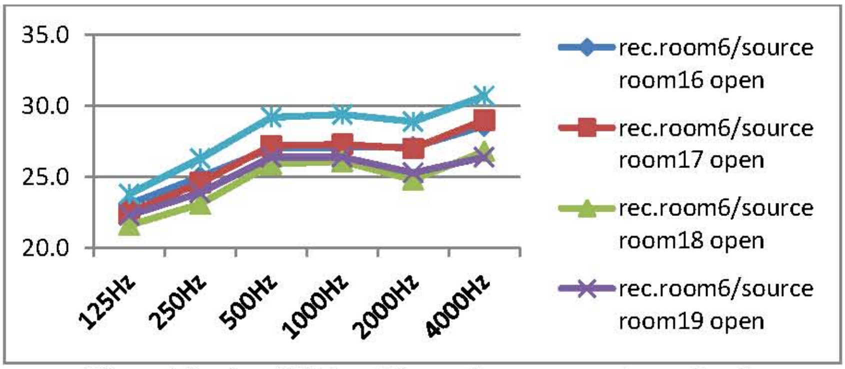

Figure 6. R values [dB] from Odeon with one open part on each wall.

In order to compare the values, sound reduction values depending on frequencies taken from laboratory measurements are given in the Figure 7. Taking both the values from Odeon and laboratory measurements into consideration, following interpretations can be done:

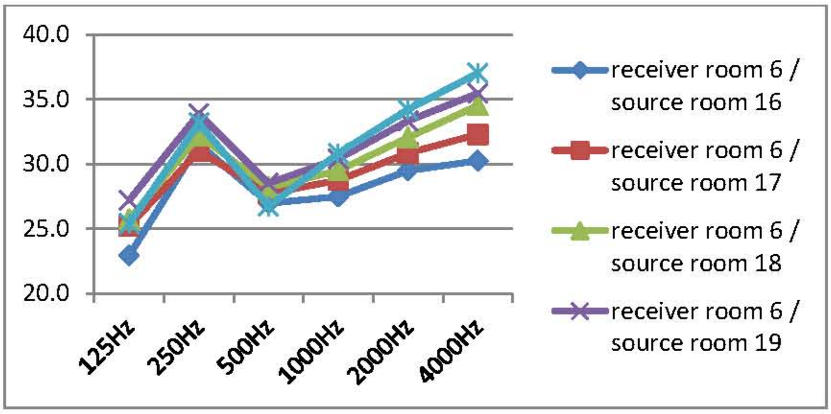

Figure 7. R values [dB] from lab. measurements with one open part on each wall.

It would have been expected that the sound reduction were greater due to diffraction effect when the distance between the inner and outer wall apertures increased. The laboratory measurements show similar results to this prediction with some differences. At high frequencies like 1000 – 2000 – 4000 Hz the order of the graphs is as it was expected; in other words, the sound reduction increased when the distances between the apertures were increased. But at 500 Hz, the case 'receiver room 6 / source room 20 open' has lowest sound attenuation compared to the other cases, while the other cases' graphs continue the predicted right order. At 125 and 250 Hz there are also some slight changes in the order of sound reduction values. It is also recognizable that all cases' R values, in general, have the tendency to increase especially at the frequency 250 Hz, while they mostly have a regularly raising graph line at other frequencies.

Analyzing Odeon calculations, same assumptions were valid again, as it was by laboratory measurements. The simulation calculations show quite different results to these predictions. The case "receiver room 6 / source room 20 open" has the highest sound attenuation at all frequencies as it was expected, but all other cases' graphs have a different order than it was foreseen. The case "receiver room 6 / source room 18 open" has the lowest sound attenuation in all the other cases, according to simulation results.

By all these five cases where the sixth panel of the receiver room wall stays constantly open, it can be inferred from the results that Odeon underestimates the sound level difference between the rooms each time. While the graph shapes of the cases derived from Odeon usually seem to have a constantly and regularly rising tendency, the actual laboratory measurements' graphs have generally an instant rise at 250 Hz and a higher rising slope at higher frequencies like 2000 and 4000 Hz. This can be caused due to the underestimation of the panels' diffraction effect by the simulation program.

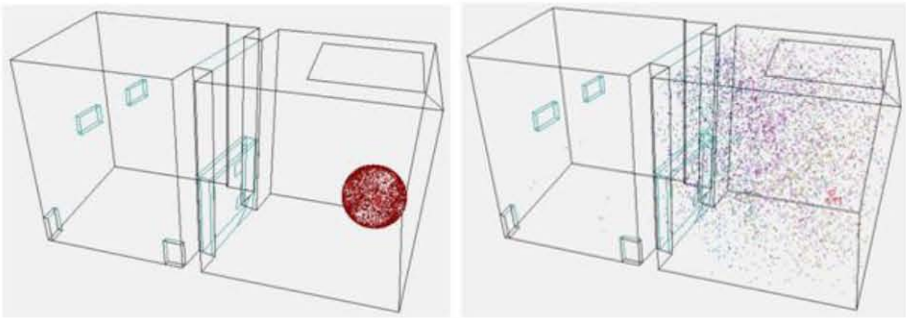

Figure 8. Screenshots from Odeon simulations.

4. CONCLUSION

This study was carried out in order to prove whether it would give reliable results or not if the research would be continued only with simulation programs. The comparisons between laboratory measurements and simulation results show that the acoustic simulation program Odeon version 9.2 is not sufficient enough to calculate the diffraction effect of the walls and the transmission of the sound through the wall at the same time, because mainly underestimated sound reduction values by the cases with openings and overestimated values by the cases with closed walls came out from the simulations. Apparently, with the calculations so far, this research cannot be continued only with computer simulations. As next steps of this research's simulation part, it is foreseen that newer versions of the program Odeon or a different acoustic program can be examined in terms of sound reduction.

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