Simulation of underground stations – a case study

Elżbieta Nowicka[1], Dirk Schröder[2]

[1] *Building Research Institute, Department of Acoustics, Warszawa, Poland, Email: E.Nowicka@itb.pl*
[2] *RWTH Aachen University, Institute für Technische Akustik, Aachen, Deutschland, Email: dsc@akustik.rwth-aachen.de*

Introduction

Underground stations are usually of non – diffuse and non – Sabine nature, which implies that the simulation of sound propagation in such enclosures cannot be solved by simple equations. However, simulations based on deterministic image sources and stochastic ray – tracing are well suitable for modeling the room acoustical parameters in such enclosures.

In this contribution the measurement results of a real underground station in Warsaw are compared to the room acoustical simulation results of a respective 3D – model. The sound field in the underground station is calculated by using two different applications, ODEON[1] and RAVEN[2], where the problem of material data and particularly the stairs' sound scattering is discussed.

Measurements

Measurements were made in "Metro Politechnika" underground station in Warsaw in Poland.

Figure 1: The view of the measured enclosure – Metro Politechnika station in Warsaw, Poland

The height and width (at level of a platform) of the measured enclosure is 6 m and 20 m, respectively. The enclosure is open at the ends by the stairs. All boundaries of the station were highly reflective. Measurements were carried out at the receiving point located at the centre of the enclosure (source – receiving distance: 60 m).

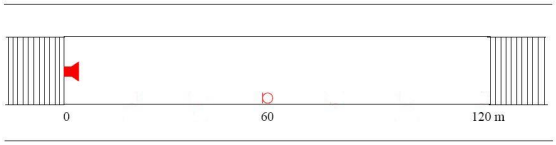

Figure 2: Measuring point used for comparison with simulation results in the paper.

Simulations

A 3D-model of a real underground station was created for room acoustical simulations (see Figure 3). The simulation's results are compared in this paper with measurement's results at the centre of the room (see Figure 2).

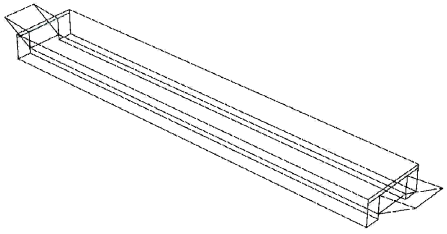

Figure 3: 3D – model of the Metro Politechnika station

Figure 4 presents a comparison of scattering coefficients used for simulations. In ODEON, the user is able to specify this coefficient only by one single number which is defined for the mid-frequency band around 700 Hz. Then ODEON expands values for each octave band [3]. In RAVEN, these values are defined for each octave band separately.

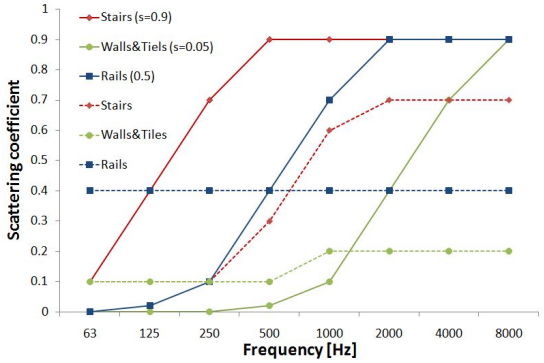

Figure 4: The comparison of scattering coefficients solid line – ODEON; dotted line - RAVEN.

Simulations were performed with the same absorption coefficients for concrete walls, floor and stairs. The side walls were covered by metal panels with unspecified absorption, which was the opportunity to an optional selection of absorption coefficients values.

Results

Simulations were made in three steps with ODEON and RAVEN applications and with different absorption and scattering coefficients.

Firstly, in ODEON the different panels' absorption coefficients were applied. The EDT values with coefficients

similar to an acoustical absorber (metal sheet with air gap – as proposed by ODEON application) were not correct in the range of low frequencies (differences up to 3 s). The new panels' absorption coefficients were then modified to obtain coincident EDT results – see Figure 5.

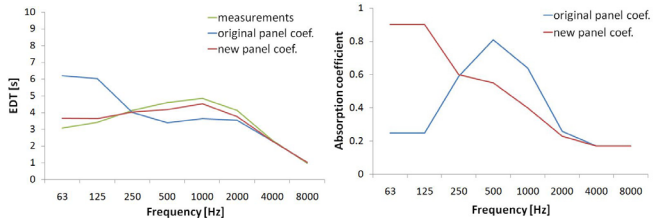

Figure 5: Comparison of simulations' results made in ODEON application with original (like for acoustical absorber) and new proposed panels' absorption coefficients – STEP 1**.**

In the next step ODEON and RAVEN were applied. Two different panels' absorption coefficients were suggested to obtain results close to measurement results of EDT values – see Figure 6. It must be noticed that different scattering coefficients were used for calculations.

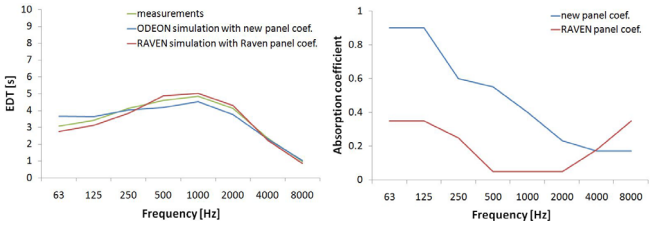

Figure 6: Comparison of simulations made in ODEON and RAVEN application with two different panels' absorption coefficients to obtain results similar to measurements' results – STEP 2**.**

Finally, the calculations in the last step were done only with ODEON application. The panels' absorption coefficient were compared those used in RAVEN – see Figure 7. The comparison indicates the significant differences among various scattering coefficients and applications' algorithms.

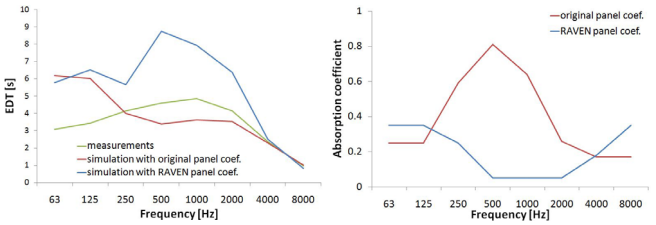

Figure 7: Comparison of simulations' results made in ODEON application with original and RAVEN panels' absorption coefficients to indicate the scattering and algorithms differnces – STEP 3**.**

Additionally, the comparison of the simulated model with and without rail–tubes (only in ODEON application) is presented in Figure 8. It indicates that scattering coefficient of the rail–tubes' walls influence the EDT results.

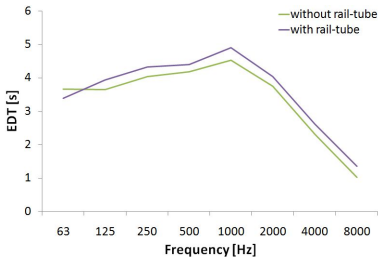

Figure 8: The comparison of simulation results from ODEON application for underground enclosure with and without rail–tubes.

Conclusions

1. In ODEON, selection of optional absorption coefficients indicates that the sound field of the simulated underground station should be highly absorptive in the range of low frequencies (63 – 250 Hz). In RAVEN, however, the same EDT is obtained by using a highly reflective character of panels. The reason for the discrepancy is probably the different handling of scattering.
2. The presented comparisons indicate significant differences between various scattering coefficients in the ODEON and RAVEN algorithms, especially in the range of low and middle frequencies. In ODEON, the highly absorption was defined while in RAVEN it drops strongly. It might indicate high overestimation of scattering coefficient's in ODEON.
3. Adding rail – tubes to the 3D – model gives slight differences in simulations (around 0.3 sec), which means that scattering coefficients of the added volume do slightly influence the EDT values.

Literature

[1] Christensen C.L., ODEON Room Acoustics Program, User Manual, Version 8.5

[2]Schröder, D., Vorländer, M., Hybrid method for room acoustic simulation in real-time, 19th International Congress on Acoustics (ICA), (2007), Madrid, Spain

[3] Christensen C.L., Rindel J.H., A new scattering method that combine roughness and diffraction effects, Forum Acusticum, Budapest, Hungary, 2005