# Overhead stage canopies – case studies

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**Summary**

Proper transmission of the sound from the stage to the audience is one of the main tasks of room acoustics. Moreover, it is also important to provide good acoustic comfort on the stage by reflecting some of the acoustic energy back to the stage. It is possible if some reflectors properly situated near the stage are used. The overhead stage canopies are commonly used as their parameters could be relatively easily controlled using simple theoretical relations. Furthermore, their position could be adapted according to the requirements of the sound source and receivers. In the paper, the authors analysed three rooms where overhead stage canopies were installed. Besides the parameters specified in ISO 3382, there were measured some spatial parameters using Soundfield microphone. In Capitol Theatre in Wrocław it was analyzed the impact of the overhead stage canopies on the room's acoustic parameters. In Arthur Rubinstein Philharmonic in Łódź some stage parameters were measured for different levels of the stage canopy. Variete Theatre in Kraków was analyzed to verify the effectiveness of developed by authors the wide band canopy. Eventually, all the results show that the simulations and calculations give values with proper accuracy with used measurement method.

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## 1. Introduction

The requirements for theatre and concert halls' acoustics, especially in terms of room versatility, are still growing. Therefore, it is necessary to use such solutions that allow to change the acoustic field in the interior. The most important room acoustic parameters are mainly associated with the delay of first reflections [1], the sound level, reverberation and spatial parameters [2] and the diffusion of the acoustic field [3]. In concert halls it is also important to provide appropriate oneself and mutual hearing among the musicians on stage [4]. The optimal values of all acoustic parameters are different depending on the room function, thus in the case of multifunctional interiors it is necessary to use elements which allow the modification of acoustics. For this purpose, there is usually used the sound absorbing material with modified surface area that affects the length of the reverberation time and moving reflective panels placed above the stage which are responsible for the delay of the first reflection, energy and spatial parameters of the sound reaching the audience.

The location of the reflective panels, their size and arrangement have been the subject of many laboratory studies [5-7] and simulation studies [8]. Nevertheless, the appearing in the literature descriptions of in-situ research are still insufficient to fully verify the simulation and modelling methods [9].

The paper presents the influence of the application and arrangement of the overhead stage canopies on the reverberation in room as well as on energy, spatial and stage parameters. The analyses are based on the research of three halls. The presented conclusions will allow to use and design reflective structures more consciously.

## 2. Studies

### 2.1. Examined objects

The analysis concerns three halls that have been recently modernized. The scope of work included, among others, the installation of some reflective panels suspended over the stage.

Capitol Theatre in Wrocław was designed for 735 people. It is dedicated mainly to present musicals, operas as well as dramatic theatres. In order to improve the propagation of sound from the orchestra pit 10 reflective panels having the dimension of 2.5 x 1.1 m were mounted over the stage and inclined at an angle of 30 degrees. The structure's height was determined by the size of the stage window and the need to preserve the functionality of the object, so the height of 7 m above the stage (10.5 m above the orchestra pit) was recommended. The main objective of the reflective panels was to eliminate the excessive delay of the first sound reflections coming from the orchestra pit to the first rows after reflection from the flat surface of the ceiling above the orchestra pit. The measurements were performed for the object without reflective panels and after their application.

In the hall in Arthur Rubinstein Philharmonic in Łódź intended for 658 people there were applied the array of 48 reflective panels with dimensions of 1.3 x 2.6 m suspended over the stage at the height about 11 m. Owing to the possibility of changing the height and an angle of inclination of each panel, the user can adjust its position to the type of performance. The studies include a comparison of two optimal (by user) settings, the first for chamber music (panels at the back of the stage inclined towards the audience, panels in front of the stage parallel to the floor) and the latter for symphonic music (all panels tilted towards the audience in the range of 12 degrees, for panels at the back of the stage, to 8 degrees for panels in front of the stage).

Variete Theatre in Kraków, designed for 394 people, were examined in terms of the acoustic characteristics of proprietary reflective panels that are effective in a wide frequency range by using scattering structures on their edges [10]. The whole array consists of 16 panels placed 6.8 m above the stage.

### 2.2. Research methodology

The measurements in all three rooms were performed using multi-directional microphones as well as a SoundField microphone which allows to separate acoustic signals from the orthogonal directions XYZ. In the case of measurements in Arthur Rubinstein Philharmonic in Łódź and in Variete Theatre in Kraków, the sound source was situated at the centre of stage at the recommended by ISO 3382-1 height of 1.5 m. On the other hand, in Capitol Theatre in Wrocław, the sound source was located in the orchestra pit. The microphones were placed uniformly over the entire surface of the audience. To obtain more accurate test results the number of measurement points was greater than it was recommended in the standard. Moreover, in Arthur Rubinstein Philharmonic in Łódź and in Variete Theatre in Kraków there was also studied the influence of the overhead stage canopies on acoustic stage parameters ($ST_{early}$, $ST_{late}$). For this purpose, the microphones were placed in accordance with the recommendations in the distance of 1 m from the sound source.

## 3. Results

### 3.1. Energy parameters

The signal that reaches the receivers consists of a direct sound and series of reflections that shape its time structure. In front of the room the direct sound dominates. Its energy decreases at points more distant from the stage. As a consequence, early and late reflections are clearly audible.

The first important acoustic energy parameter is the sound strength G, that is the total level of sound reaching the listener, defined as the sum of the direct sound energy, energy derived from the early reflections (up to 80 ms) and energy from the late reflections (later than 80 ms). The intensity of the decrease in the value of parameter G with a distance from the sound source is associated with a reverberation in an interior. It also depends on the early reflections which might be shaped for example by overhead stage canopies. Another important energy parameter is the sound clarity C80 that is the ratio of early to late energy.

In the hall of Capitol Theatre in Wrocław, after installation of reflective panels over the orchestra pit, there was observed an increase in the values of the parameter G in the middle and the back of the ground floor as well as under and on the balcony (Fig. 1). The used solution allowed to offset the excessive reductions in the value of G in these audience areas by providing more early reflections energy.

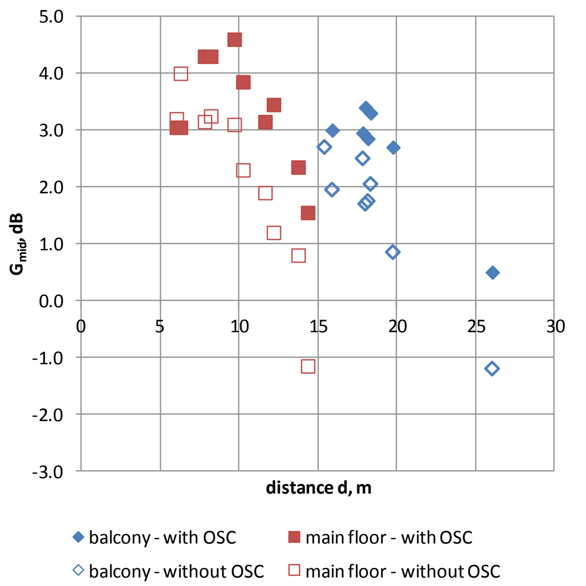


Figure 1. The values of sound strength G before and after installation of reflective panels above the stage in Capitol Theater in Wrocław

In Arthur Rubinstein Philharmonic in Łódź, the change in an arrangement of reflective panels from chamber into symphonic setting caused the increase in sound volume in the rear part of the room and thus the increase in the value of parameter G in this area (Fig.2).

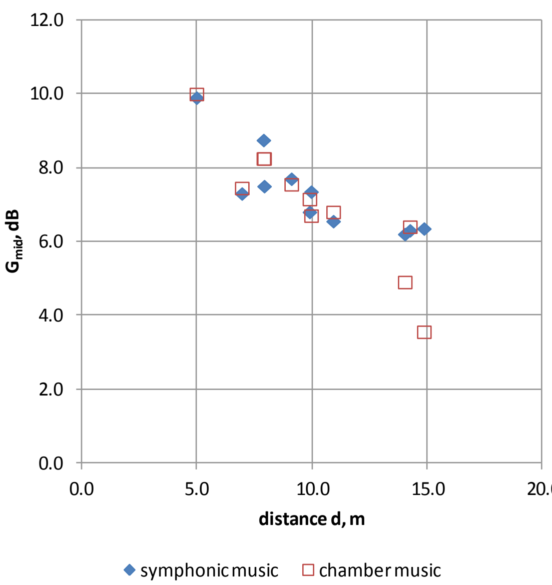


Figure 2. The values of sound strength G in Arthur Rubinstein Philharmonic in Łódź for chamber and symphonic arrangement of reflective panels

In the hall of Variete Theatre in Kraków, it was observed a significant change in the values of sound strength G depending on the sound source location on the stage (Fig. 3). By moving the source from the position S1 to positions S2 and S3 in the back of the stage, the reflection zone of overhead stage canopy moved toward the middle and rear areas of the audience. As a result, the values of parameter G increased in these regions, however, they decreased in the first rows.

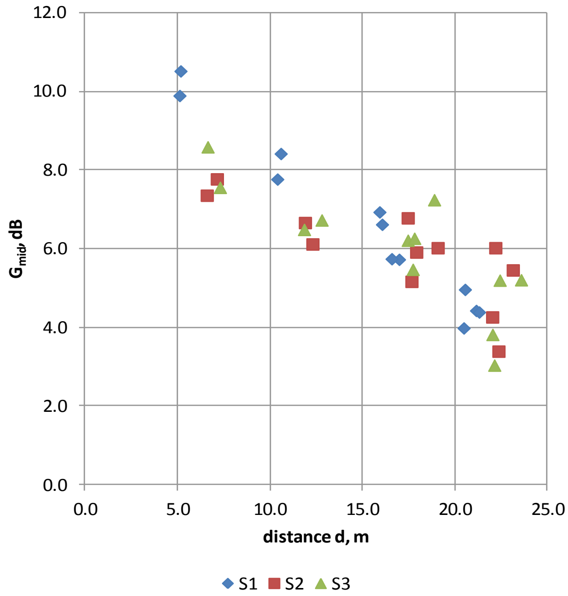


Figure 3. The values of sound strength G for different sound source positions in Variete Theater in Kraków

The analysis of changes in the values of sound clarity C80 showed that in audience areas where reflections from panels were directed this parameter also increased. In Capitol Theatre in Wrocław the highest increase was recorded for the middle of the audience and the front rows of the balcony where the values increased by more than 3 dB (Fig. 4).

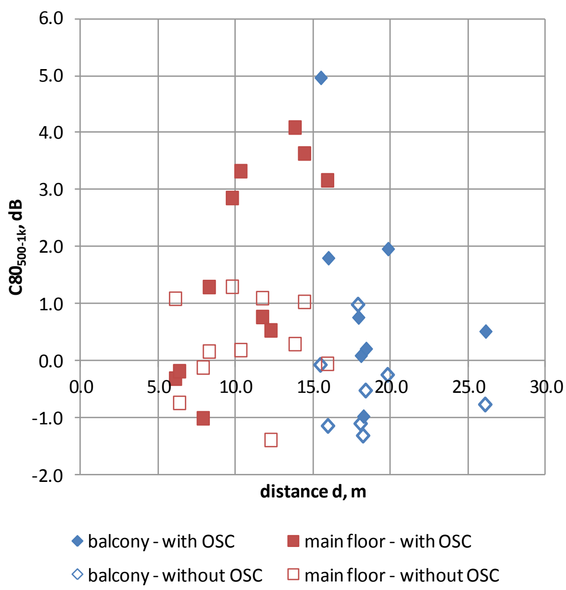


Figure 4. The values of sound clarity C80 before and after installation of reflective panels above the stage in Capitol Theater in Wrocław

The change of the reflective panels' position in Arthur Rubinstein Philharmonic in Łódź also provided the increase in values of parameter C80 by about 3 dB in the middle and at the back of the room (Fig. 5).

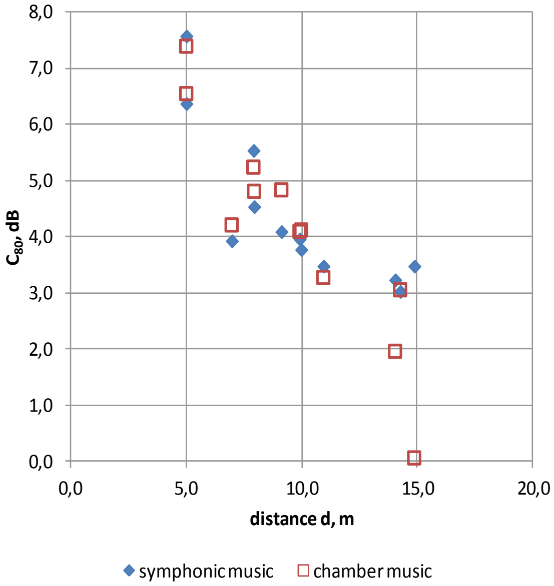


Figure 5. The values of sound clarity C80 in Arthur Rubinstein Philharmonic in Łódź for chamber and symphonic arrangement of reflective panels.

A similar situation occurred in Variete Theatre, where the moving of the sound source deeper into the stage also caused an increase in the value of C80 at the back and in the middle of the audience.

### 3.2. Spatial parameters

All performed measurements show that the change in the arrangement of suspended over the stage reflective panels had no significant effect on the acoustic spatial parameters LF and 1-IACC. It is due to the fact that these parameters define the energy coming from the lateral directions whereas in the present case, only the energy coming from the top and front of the audience changed. The obtained values of both of these parameters are shown as an example of Arthur Rubinstein Philharmonic in Łódź (Fig. 6 and Fig. 7).

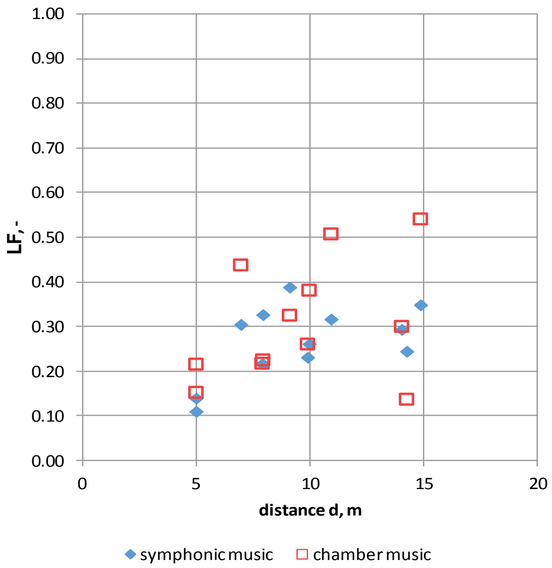


Figure 6. The values of parameter LF in Arthur Rubinstein Philharmonic in Łódź for chamber and symphonic arrangement of reflective panels

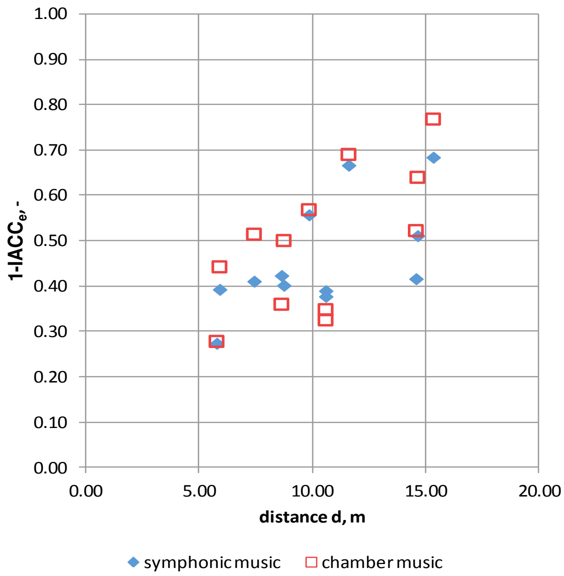


Figure 7. The values of parameter 1-IACCe in Arthur Rubinstein Philharmonic in Łódź for chamber and symphonic arrangement of reflective panels

### 3.3. Stage parameters

The analysis of acoustic stage parameters was carried out for Variete Theatre in Kraków and Arthur Rubinstein Philharmonic in Łódź. According to ISO 3382-1, two stage parameters were calculated, the first, $ST_{early}$ which describes the oneself and mutual hearing among the musicians and the latter $ST_{late}$ which expresses the audibility of interior's reverberation. As shown by previous studies [11] in the best concert halls the values of $ST_{early}$ are greater than -15 dB, however, according to the study [12] the most preferred values are in the range of -10 to -12 dB.

The values of parameter $ST_{early}$ obtained in Arthur Rubinstein Philharmonic in Łódź for symphonic arrangement of reflective panels and for the points located near the edge of the stage are lower than -15 dB (Fig. 8), which could result in problems with hearing by the musicians themselves in these regions of the stage (the first violins, cellos). The improvement was achieved by setting reflective panels in a position parallel to the surface of the stage, i.e. in the chamber arrangement. Then, there was also improved the parameter $ST_{late}$.

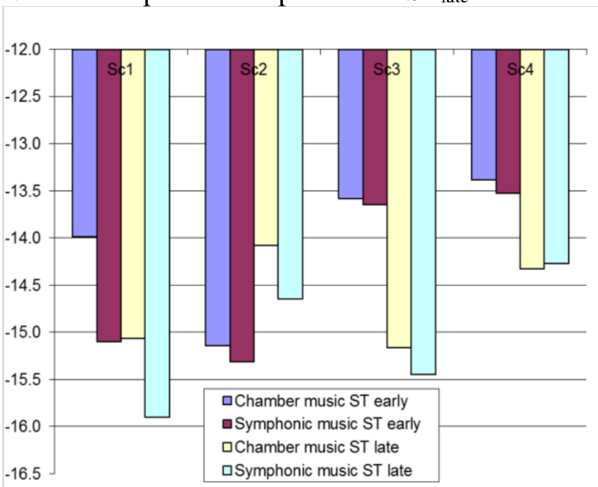


Figure 8 Stage parameters depending on the position of the sound source and reflective panels' arrangement in Arthur Rubinstein Philharmonic in Łódź

In Variete Theatre, by the use of a proprietary reflective-diffusing panel, high values of the parameter $ST_{early}$ (-11.7 dB) and the uniform frequency response (+/- 2 dB in the range of 250-4000 Hz) were obtained.

## 4. Conclusions

The obtained results confirm the impact of overhead stage canopies on the shaping of acoustic conditions, both in the audience and on stage.

The change of the acoustic parameters in the audience was evident, especially in terms of improvement of conditions in places away from the stage and under balconies which resulted in an alignment of the sound energy reaching the individual listeners. Moreover, in these areas the distribution of parameter C80 was also improved, which translates into more incisive perception of music. Further, it was shown a significant impact of the suspended reflective panels on the acoustic conditions on stage, especially with regard to the parameter $ST_{early}$.

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