Effectiveness of Acoustic Banners Depending on their Arrangement in the Concert Hall – Case Study

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Abstract

One of the most frequently used methods of adjusting the room acoustics of concert halls is the temporary introduction of additional acoustic absorption in the form of acoustic banners. Banners are implemented in the form of fabric surfaces placed vertically or horizontally along the walls of concert halls. In practice, one or two layers of heavyweight fabrics are used, characterized by a high value of the sound absorption coefficient. Simplified methods of designing acoustic banners assume estimating the effectiveness of adjusting the reverberation time on the basis of the static theory. The paper presents the results of measuring the effectiveness of acoustic banners carried out in the concert hall. The possibility of tuning the interior acoustics was verified depending on the position of the banner in the room as well as the degree of its opening.

Keywords: room acoustics, adjusting room acoustics, acoustic banners, multipurpose venues

1. Introduction

The necessity to hold varied events in one room leads to the need for adjusting to very different acoustic requirements [1-3] within a single room, depending on each event's particular characteristics. Experiences gathered when designing [7-9] and executing adjustable acoustics for venues located in Poland were used as well.

In the case of adjusting the acoustics of concert halls with relatively small cubic volume, there are problems related to the installation of acoustic banners with active surface sufficient for obtaining the expected level of the reverberation time adjustment capacity. Therefore, the decision was made to research the issue of the impact of the arrangement of banners on their effectiveness. This topic will be further explored in subsequent papers on the subject of methods of acoustic adjustment in multi-purpose venues.

The article is a case study based on results of measurements made in the recently designed concert hall at Mieczysław Karłowicz Primary & Secondary Music School in Katowice [6].

2. Methods of Adjusting Acoustics

Some discussion about methods of adjusting acoustics was presented in the previous papers [4, 5]. Classic methods of acoustic adjustment are based, among others, on the well-known Sabine's equation (1).

$$RT = \frac{0.161 \times V}{A} = \frac{0.161 \times V}{S_1 \cdot \alpha_1 + S_2 \cdot \alpha_2 + \ldots + S_n \cdot \alpha_n} \text{ [s]} \quad (1)$$

The reverberation time RT is directly proportional to the cubic volume of the room V and inversely proportional to the acoustic absorption A of the entire room. The acoustic absorption A of each of n surfaces/elements in the room is the product of the surface area S and the acoustic absorption coefficient α of a given element. We can, therefore, directly influence the reverberation of the room by changing its cubic capacity (using reverberation chambers or lowering the acoustic ceiling), or introducing elements (rotating acoustic panels, acoustic roller banners) with a different acoustic absorption coefficient α.

The most popular method of mechanical adjustment of the reverberation time is the introduction of textile curtains – acoustic roller banners – to the room [5]. The basic principle is to place in front of a surface with a small coefficient α value a piece of fabric with a significantly larger α value. Thus, the sound energy reflected from this surface is effectively decreased, which leads to decreasing reverberation energy in the room, and thus, directly decreasing the RT value.

3. Tested arrangement of acoustic banners

The study was conducted in the concert hall at Mieczysław Karłowicz Primary & Secondary Music School in Katowice, a typical shoebox-shaped space. In 2016, design documentation for a complete renovation was prepared [6] and used in 2017-2018 to perform a comprehensive overhaul. Dimensions and shape of the hall's external walls result from the space initially intended for the concert hall. They could not be modified during the renovation due to volume and construction limitations of the school building.

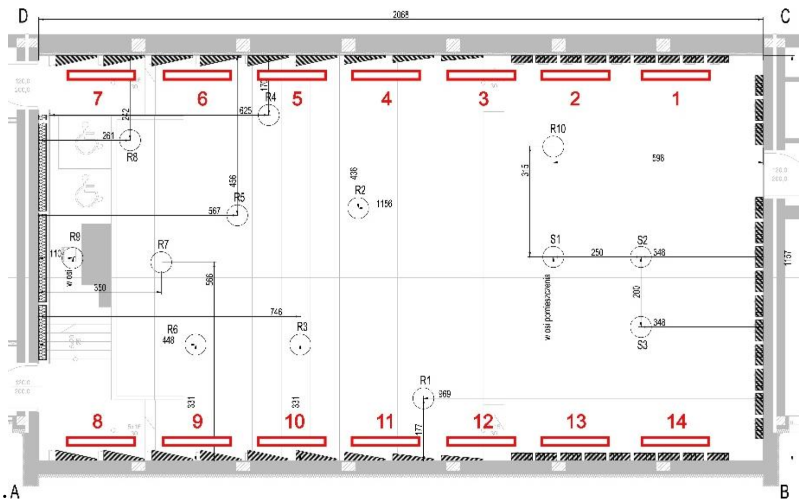

Figure 1. Plan of the measured concert hall. Placement of the acoustic treatment, acoustic banners (numbered in red) and measurement (source and receiver) points

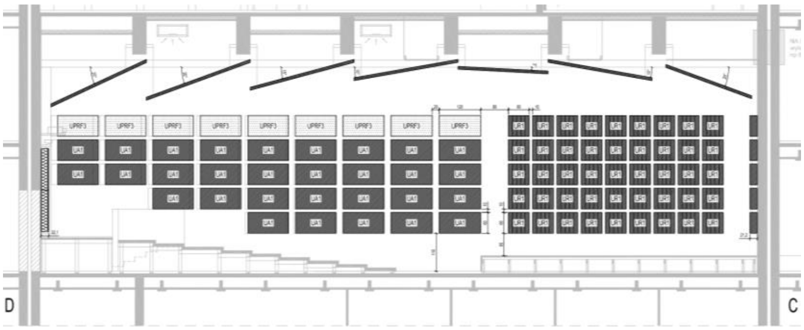

Figure 2. Section view of the left wall of the measured concert hall

Figure 1 features the plan of the room with the placement of the wall acoustic treatment, acoustic banners (numbered) and measurement points used in the acoustic study. The room is symmetric with respect to its main axis, except for the location of the entrance door to the stage and stairs leading to the sound engineer's station.

Above the stage and auditorium, reflective acoustic ceiling panels are placed (Figure 2). On the front (Figure 4) and side walls (Figures 1, 2) in the stage area, dispersing panels are located. Reflective and absorbing panels for the controlled scope of frequencies are located on side walls (Figure 2) in the auditorium area. The back wall (Figure 4) is entirely covered with broad-range absorption panels. The stage has the classic construction of a philharmonic floor with planks laid on wooden joists. The auditorium floor is slightly ascending. There is a sound engineer's *Front of House* station in front of the back wall, separated from the audience with a reflective barrier.

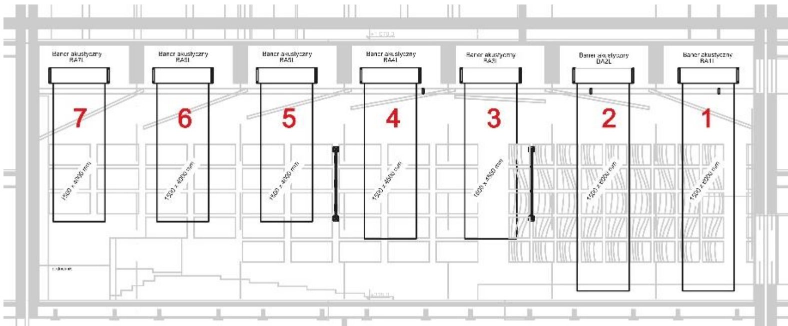

Figure 3. Acoustic banners' placement on the left wall of the measured concert hall

Acoustic banners are placed symmetrically along the side walls of the room (Figures 1, 3). Banner cases are placed above acoustic ceiling panels, and thus when completely closed, banners are not visible from the room, nor do they affect the room acoustics. The banners used are composed of a single layer of fabric, 150 cm wide, with the acoustic absorption class A. Figure 3 features banners opened to the degree established in the design documentation as the maximum opening which precludes collision with audience members walking the stairs. For situations described below as banners opened at 100%, the lower edge of banners almost reached the floor of the stage or auditorium.

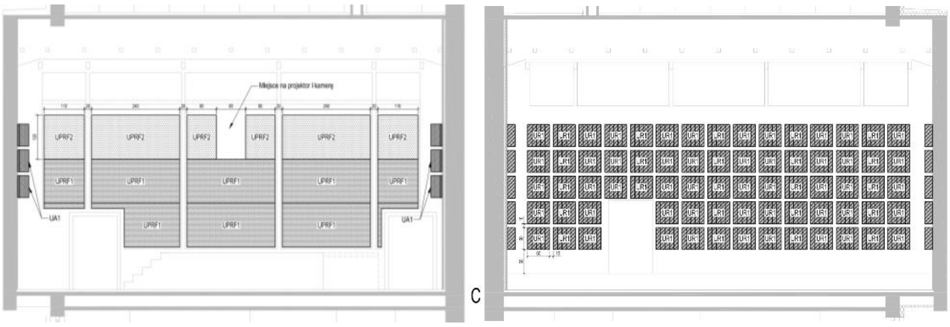

Figure 4. Section view of the back wall (left)
and front wall (right) of the measured concert hall

During the study, 3 locations of measurement sources (S1–S3) were used, as well as 10 locations of measurement microphones (R1–R10), which amounts to 30 measurements in total for each studied situation (banner arrangement). The study used a multi-channel measurement system with a 12-sided sound source as well as omnidirectional measurement microphones compliant with the current standards of interior acoustics measurements, including the PN-EN ISO 3382-1:2009 norm. Measurement points were selected at the stage of designing the hall acoustics mainly due to their representative character in displaying acoustic properties of the room during modelling, and then during measurements.

4. Measurement results for various arrangement of acoustic banners

The banner control system enables rolling out both individual banners and their groups independently, and to different degrees. A fully opened banner was marked as 100%, while the absorbent fabric completely hidden in its case was marked as 0%.

Figure 6 presents the results of the first series of measurements in which all banners were opened to the same degree. T20 reverberation time values were measured with:

- banners fully hidden (0%),
- 6 situations when banners were rolled out by additional 15% (15%, 30%, 45%, 60%, 75%, 90%),
- banners fully opened to 100%.

The analysis of results presented in Fig. 5 indicates that the smallest changes in the T20 reverberation time were obtained for 60%-100% situations. The greatest changes were obtained in the first phase of opening, i.e. 0%-45%. This allows for the conclusion that in the case of the studied hall, the first portion of the opened acoustic banners has a stronger impact on the resulting outcome of frequency characteristics of the T20 reverberation time than the last portion of these banners. It is probably due to the fact that the increase of acoustic absorption A is higher at the beginning of banner's opening phase than at the end of opening phase.

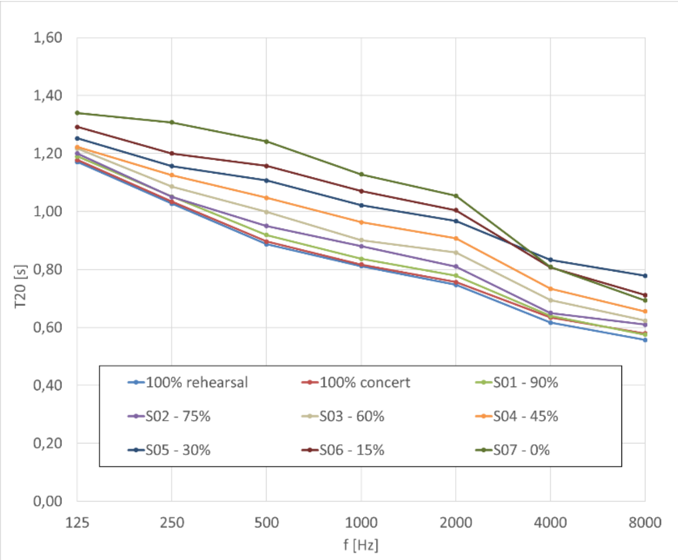

Figure 5. T20 in the function of banners' opening degree

This situation can be explained alternatively by the fact that lower portions of side walls, due to the close proximity of very absorbent audience seats, are less effective in creating the reverberation effect resulting from reflecting sound waves. This conclusion should be, of course, verified with research on a larger sample of concert halls, which has been included in the further scheduled studies on the topic.

Subsequent tests concerned the impact of the arrangement of acoustic banners in the room on the obtained reverberation time values. Within this test, selected groups of banners were being completely opened (100%), while others were fully closed (0%).

In the second series of measurements (Figure 6), banners were rolled out in groups of 2 on each side of the room. Therefore, in this series, there were always 4 banners (2 on each side) fully opened (100%) at any given time. The series of measurements started from the situation T11, when banners (1, 2, 14, 13) located on the stage were opened. Subsequent measurements were made for groups of opened banners increasingly distant from the stage (T12, T13, T14, T15). In the last tested situation T16, the last two banners (6, 7, 9, 8) on each side were opened.

The third series of measurements (Figure 7) was made similarly to the second one, only in this one groups of 3 banners were opened on each side, starting with the ones closest to the stage (situation T21 – banners 1, 2, 3, 14, 13, 12), ending in the back of the auditorium (situation T25 – banners 5, 6, 7, 10, 9, 8).

The fourth series of measurements (Figure 8) was made similarly to previous ones, only in this one groups of 4 banners were opened on each side, starting closest to the stage (situation T31 – banners 1, 2, 3, 4, 14, 13, 12, 11), and ending in the back of the auditorium (situation T34 – banners 4, 5, 6, 7, 11, 10, 9, 8).

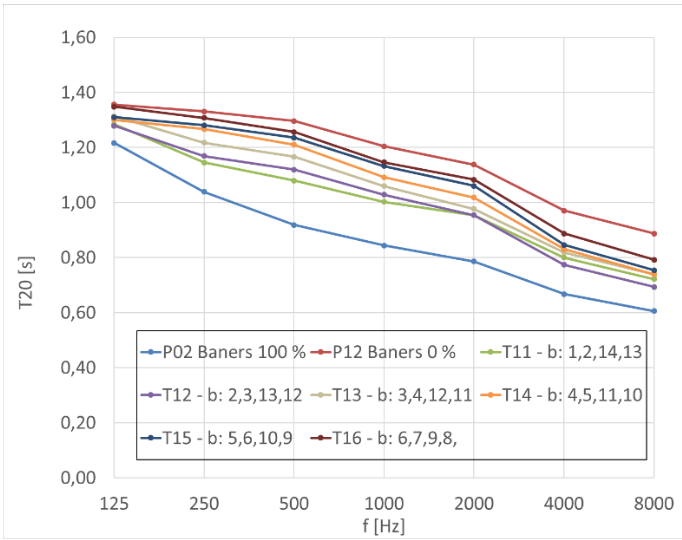

Figure 6. T20 in the function of banner positions.
Banners 100% opened in groups of 2 per side wall

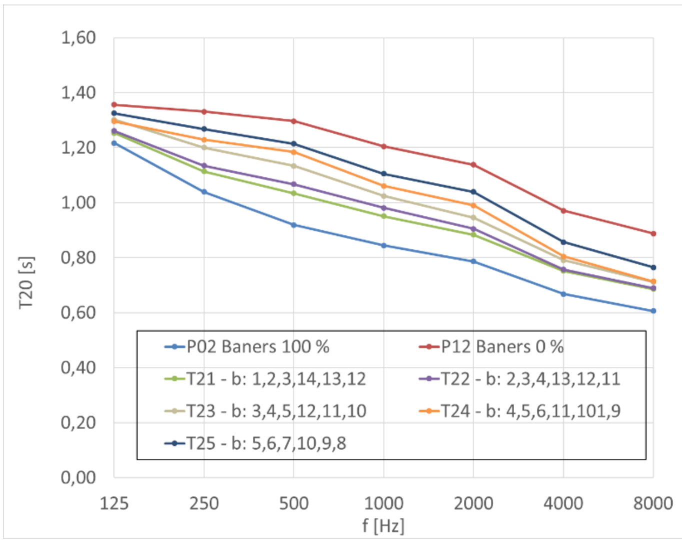

Figure 7. T20 in the function of banner positions.
Banners 100% opened in groups of 3 per side wall

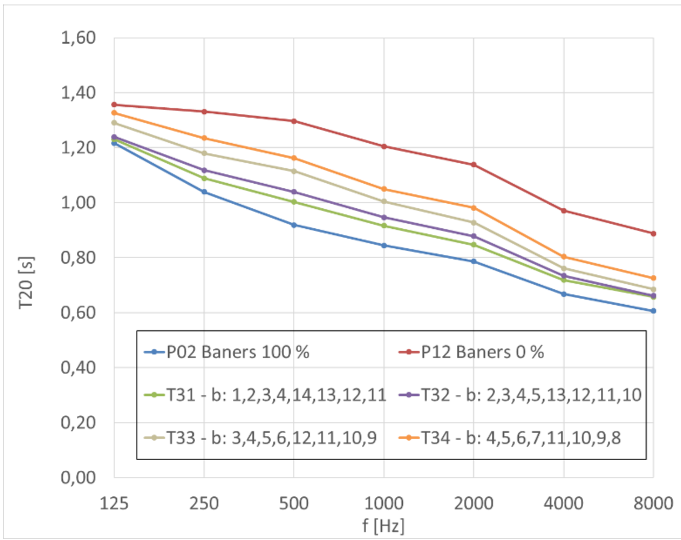

Figure 8. T20 in the function of banner positions.
Banners 100% opened in groups of 4 per side wall

The analysis of results featured in Figures 6-8 indicates that the impact of acoustic banners on the obtained value of T20 reverberation time drops as the distance from the stage grows. This relationship is more pronounced when 4 banners per side were opened (Figure 8) than when groups of 2 banners per side were opened (Figure 6).

This situation can be explained in two ways. The first factor influencing this fact is a slightly decreasing surface of banners as the distance from the stage increases, which results from the ascending auditorium floor. However, differences between the surface of banners are not as large as differences between RT values obtained as a result of their opening.

The second possible explanation is that when banners closer to the stage are opened, suppressed are side surfaces that create mostly first order reflections. In the case of surfaces further from the stage, suppressed surfaces are those responsible to a larger degree for creating reflections of higher orders, and to a smaller extent of first order reflections. Thus, surfaces located further from the stage are less effective in creating the reverberation effect, which makes it less effective to cover them with acoustic banners in order to readjust reverberation time, than covering surfaces closer to the stage.

5. Conclusions

The conducted tests indicate that acoustic banners located closer to the stage are more effective in adjusting the reverberation time value than banners located in the back portion of auditorium side walls in the presented case.

Moreover, a stronger impact on the change of the reverberation time was noted in the case of banner surfaces opened at the initial phase of their opening, in comparison to surfaces activated at the end of the banner's opening.

The presented conclusions were derived from measurements and studies conducted in just one concert hall. To verify the accuracy of the results featured in this paper, further broader research including other concert halls is planned.

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