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ACOUSTIC DESIGN CHALLENGE IN TOTALLY FLEXIBLE CONFIGURATION OF THEATRE HALL – CASE STUDY

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Abstract: *Modern trends in theatres require from engineers to design some new flexible forms of rooms for dramatic play. One such form is a hall without defined auditorium configuration and a separated stage tower equipped with mechanical and other stage gears, but rather as volume organized in a whole as the stage tower, which includes a height exceeding 20 m all around the hall. Such space trend entails utilizing some stage machinery with the aim of organizing various configurations of the auditorium. In such circumstances, the percentage of surfaces which theoretically can introduce some positive contribution to theatre hall impulse response has been greatly reduced. At the same time, a large part of the interior surfaces can undoubtedly have negative effects on response, mostly owing to huge height of the ceiling. Those circumstances represent a challenge for a designer to create some new forms of interior solutions which, in such limited circumstances, would create an acoustic quality of the impulse response. One such space is the hall of National theatre in Subotica, Serbia, which is currently under reconstruction. Its dimensions are approximately 30 x 18 x 22 m, and concrete have to be the material at interior surfaces (due to architectural ideas). Possible forms of acoustic design solutions for this hall have been tested. The paper contains the results of the analysis carried out by means of the scaled model accompanied by software simulation.*

Key words: acoustic design, flexible acoustics, impulse response, theatre hall

1. INTRODUCTION

Contemporary drama production constantly searches for new space forms and for new drama plays' framework. Stage spaces' changes had occurred through avant-garde theatre movements and theatre arts in the twentieth century. This was a theatre that had wished to destroy both social and spatial boundaries, thereby requiring a dedicated viewer, who often becomes a participant in the creative theatre act. Such a theatre seeks a cleaned, demystified and emptied space for its play in which it would insert energy. This type of demand is the opposite of the ornate traditional theatres built for the elite. The most direct result of these trends is the occurrence of drama plays that were played outside the institutionalized theatre buildings, because the artists had regarded them as inappropriate due to their classical space form.

These theatre development trends caused the classical form of the theatre hall, which contains the baroque “picture frame stage”, to become the object of constant review and analysis in architectural theory of performance spaces. There is constant dialogue in planning and construction between the theatre (directors, set designers, theatre artists) and the architects and other engineers involved in the design process. This was confirmed by different theoretical and research papers published during the twentieth century (and often labeled as “theatre for the new century”).

Modern performance space architectural development trends have generated a new form of theatre hall in that process of constant reviewing the physical framework for dramatic play. Their features can be briefly summarized as two important characteristics: flexibility, which means adaptability to different theatre authors' requirements, and a shift from conventional forms of scene-auditorium. In order to achieve this, the whole area becomes a unique theatrical hall without a permanent portal and accompanied by technical stage equipment throughout its whole space. The characteristic example of such space, which is often referred to in the literature, is the Schaubühne hall in Berlin [1]. That hall consist of a relatively large area bounded by concrete walls, with technical “grid” along the entire surface of the hall and with technical etage above it.

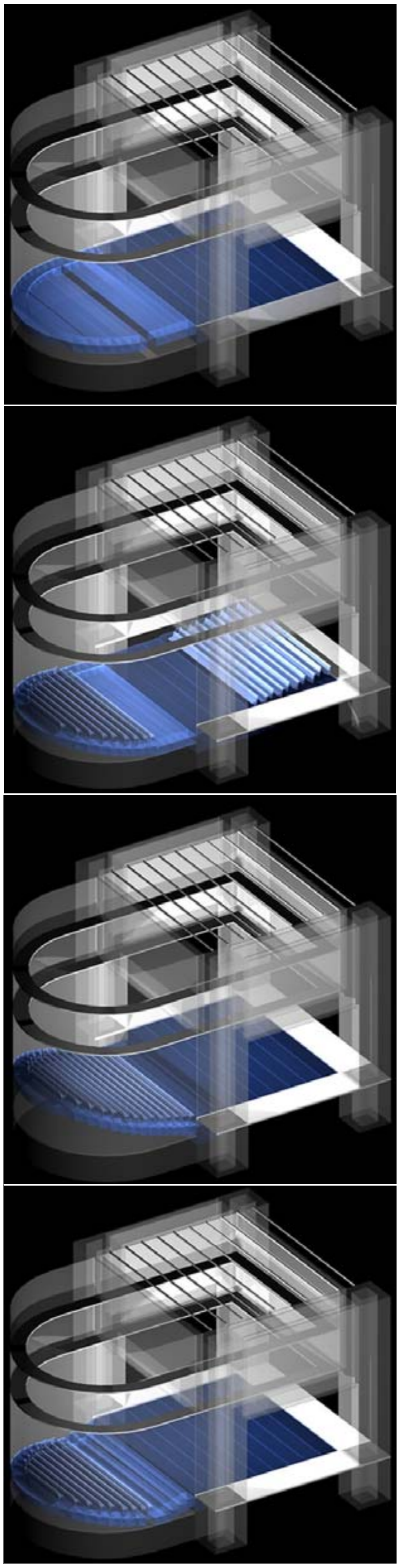

Fig. 1 Some configuration options for the hall of National Theatre in Subotica

A variety of special curtains and screens, removable panels and similar devices offered by modern stage systems are used with the aim of adjusting the hall, as well as mobile platforms that can be raised and lowered and by means of which the geometry of the floor is being formed. Decorative elements in the hall are "sacrificed in favor of functionality, resulting in a sober but purposeful configurations" [2].

An example that follows such an idea today is the main hall of the National Theatre in Subotica, Serbia. This theatre's building is currently under construction. Depending on a type and manner of a particular dramatic play as well as the director's ideas it is possible to change the configuration and the formation of a two- or three-sided audience in the hall. In addition to this, it is also possible to have just one stage-audience space or even to have classical model of drama hall with portal barrier formed as scenery. The idea of such a concept is that the full unity of the stage and the spectator area can be achieved, while simultaneously and according to need creating studio area of significant size, adequate for the assumed requirements or a conventional theatre hall. Some basic customization options for the hall of the National Theatre in Subotica aimed at conforming with different drama requirements are shown in Figure 1: from two-sided auditorium with space for play between them up to the completely flat area of studio type.

The changing of ideas concerning theatre hall configurations and a shift from the classical relations scene-auditorium was accompanied by a change of views on the aesthetics of such a design. Contemporary aesthetics of such areas has caused designers to reject the insertion of usual interior design materials in the visible part of the hall, even those traditional materials required for adjusting acoustic response. High flexibility of the hall, which is the primary request in its design, and the effect that it produces in its interior, have produced a special challenge in the acoustic design of such space. It is caused by the need that the measures, which are taken in the hall to adjust the acoustic response, must not compromise the required aesthetics of the interior of reduced lines and materialization. In such spaces' architecture, concrete is preferred as final, visible layer of the walls. At first glance, this particularly limits the maneuvering space for any acoustic design interventions. Theatre artists working in Schaubühne in Berlin [2] highlight the inevitable acoustic problems in such circumstances.

2. HALL OF THE NATIONAL THEATRE IN SUBOTICA AND ITS MODELS

The form of the designed hall of the National Theatre in Subotica is presented in base and cross section in Figure 2. Dimensions of the hall are 29 x 18 m in the base and its height is about 22 m. The total hall volume is about 10,000 m^3. There is a technology grid (grid deck) at the height of 18 m above the floor, and it defines the height of the visible part of the hall volume. There is mechanical equipment for stage technology above the grid. Therefore, the entire room has the capabilities of a typical stage tower that includes all kinds of flying bars and reflectors holders for support of the events in hall.

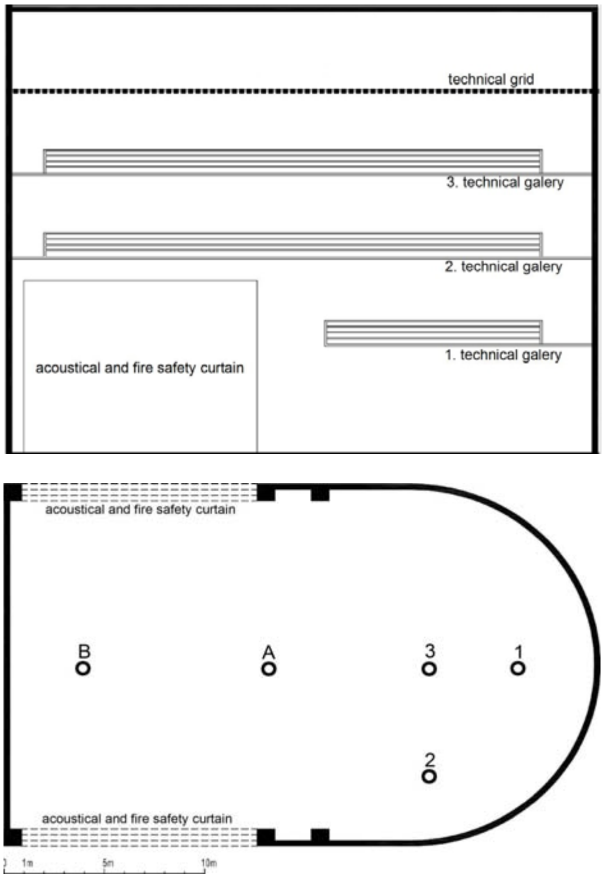

Fig.2 Base and crossection of the analysed hall; the positions of sound source (A and B) and receiver (1,2 and 3) used in the anaysis are marked at the hall base.

Fig. 3 The exterior of the hall scaled model

Along the perimeter of the hall there are three technical galleries the first of which is the lowest one and can be used for the audience in some conditions, too. There are large acoustical and fire safety curtains on both sides occupying large part of side walls, as indicated in Figure 2. By opening these curtains the space of the hall can be optionally connected with neighboring areas (these are two adjoining halls) forming a single large space. The hall does not have a fixed auditorium, and its basic configuration is the flat floor over the entire surface. At both ends, there are platforms in the floor which can be elevated, thereby forming a cascade of different variants of the auditorium, as shown in Fig. 1. The hall cross section presented in Fig. 2 shows the basic variant with a completely flat floor. All analyses the results of which are presented in this paper were performed for that hall's configuration.

Fig. 4 A part of the interior in the scaled model

The physical model scaled 1:10 was made for the analysis of the hall acoustic response. As a result of the size of the model in this scale (3x2x2 m), it is made in three parts the assembling of which makes the complete hall. The external look of the model is shown in Fig. 3, and a part of its interior in Fig.4. In addition to the scaled model, the software was also made in Odeon, which was utilized in order to have some of the results checked. In this way, the conditions, which can be used in its acoustic design, are created for an analysis of the various modifications in the hall.

At the moment of performing the analysis the results of which are presented in this paper, the hall was already built, but without any intervention in its interior. All surfaces were bare concrete, and the acoustical and fire safety curtains were not mounted, so there were large openings at their positions. The existence of the hall in such a state allowed some measurement and verification of the measurement methodology used in the scaled model.

3. POSSIBLE INTERVENTION TYPES IN THE HALL

The interior designers had defined the basic visual character of the hall, from which they derived some limitations in relation to the acoustic design. In such spaces, the request of the modern design requires that all visible surfaces are made in natural concrete. In the hall, as presented in Fig. 2, it means that the surfaces of the visible walls are up to the level of the second technical gallery. Possible interventions on the walls are hardly noticeable from the floor above that level, particularly due to the normal lighting concept in theatre halls. Therefore, it is allowed to set some arbitrary acoustic interventions on the walls above that height.

The analysis of all restrictions has defined the space in which one can look for acoustic solutions for the given size and shape of the hall such as the theater hall in Subotica. The conclusions clearly show that the available means for acoustic design can be summarized as follows:

- Installation of efficient absorptive materials is possible only on the parts of the interior surfaces which are invisible for visitors, and those are the surface of the ceiling, parts of the walls above the technical grid and walls below the grid in the part which is high enough that will not be visible, which practically means above second technical gallery;
- It is possible to apply some form of relief on concrete surfaces, but they have to be made of concrete, too;
- Deviation from verticality on the walls is possible only in the form of horizontal galleries that can be made reflective and as such, they bring diffuseness into space.

Fig. 3 The schematic presentation of acoustics interventions in the hall: 1, 2 and 3 - high efficiency absorbing material, 4 and 5 - relief that may be normal or complex (lower and higher value of scattering coefficient)

The scope of such intervention and whether the acoustic response, which would be appropriate for the theatre hall, can be achieved, were analyzed by measurement in the scaled model. The following interventions were successively introduced in the model and tested by measurement (all those interventions are schematically indicated and numbered in Fig. 3):

1. on the surfaces above the technical grid (ceiling and walls) an efficient absorption material is placed (number 1 in Fig. 3);

2 An efficient absorption material is placed on the upper parts of the walls, between second gallery and technical grid, along the perimeter of the hall (2, 3);

3 On the lower two technical galleries the floor is made of hard material thereby introducing a horizontal reflective surface which makes reflections to the floor to some extent;

4 Some relief, which has to be made of concrete, is located on the lower parts of the curved wall, from the floor to the level of second technical gallery (4);

5 The relief, which has to be made of concrete, is located on the back wall of the hall, between the openings for acoustical and fire safety curtains (5);

6 An enhanced relief is introduced with higher value of scattering coefficient at all surfaces with relief (4 and 5).

4. THE ANALYSIS OF THE HALL IMPULSE RESPONSE WITH DIFFERENT INTERVENTIONS

All of the described interventions in the hall were introduced successively in the scaled model. The reverberation time and the impulse response structure were analyzed for each change. It is obvious that introduction of the absorption in the room affects the decrease of the reverberation time value, but such a process inevitably reduces the energy that reaches the listener at the interval important for perception, because it reduces the total amount of energy that arrives. Therefore, the energy changes in the initial part of the impulse response were also analyzed.

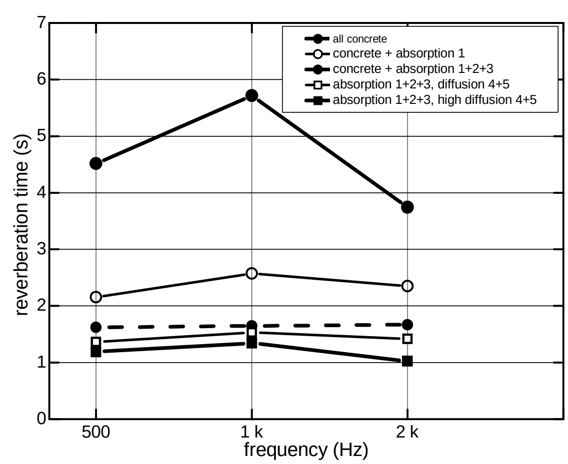

Fig.6 The results of reverberation time measurements

The results of the reverberation time measurement in the model for all successive changes are shown in Fig. 6. The results are presented for the three central octaves: 500 Hz, 1 kHz and 2 kHz, respectively. The sound source positions (indicated by letters) and receiver positions (indicated by numbers) are presented in Fig. 2. All those points were at a height corresponding to the height of the man's head standing on the floor. The Fig. 6 contains the diagrams for the previously explained successive changes in the hall, in addition to diagram for initial state of the hall before any intervention (indicated by "all concrete").

The diagram presented in Fig. 6 reveals that the basic configuration of the hall with bare concrete walls has a reverberation time of about 5 s in the central octaves. This value is measured in the existing state of the real hall, and that served for control of scaled model measurement. Starting from the ceiling down to the level of the second technical gallery, the ongoing introduction of absorptive material gradually reduces the reverberation time. However, the diagram shows that adding the relief in the lower part of the walls has an effect that contributes to further reverberation time reduction. This is caused by the sound energy traffic change in the hall that occurs due to the dispersion of reflected energy from the walls and platform of two galleries. That effect increases the probability of energy hitting the absorption material in the upper part of the hall, thereby changing the distribution of angles of incidence which increases the absorption coefficient effective value of the same material [3]. The final result, obtained with the applied absorption and relief with scattering coefficients' higher value, meets the criteria for the reverberation time value in the hall for the given volume (10.000 m^3).

The arrival of energy in the early part of impulse response was analyzed in addition to the reverberation time. The interval of 100 ms was observed, which is important for the perception of sound. The structure of the impulse response was quantified by cumulative function of energy arriving at the receiver, and its value is normalized to the direct sound energy. Such value represents the reverberation gain influenced by early reflections. Some of the results obtained by measurements in the scaled model are presented in Figs 7, 8 and 9.

The presented results show that the gain in the hall decreases with entering the absorptive material, but increases with introduction of the diffusion in the lower part of the concrete walls surfaces. This is due to the fact that the diffuse reflections at each point of the audience provides additional amount of the first reflections energy. Therefore, entering the relief at wall surfaces increases the gain in auditorium [4].

In order to show this rule more clearly, in Fig. 10 the change of gain measured in the model as a function of reverberation time is presented. The diagrams are shown for the same combination of excitation and reception points as in Figures 7, 8 and 9. The diagram shows that the introduction of diffusion in the room increases the gain while additionally reducing the reverberation time. The minimum of each curve corresponds to the maximum absorption in the hall without any additional relief.

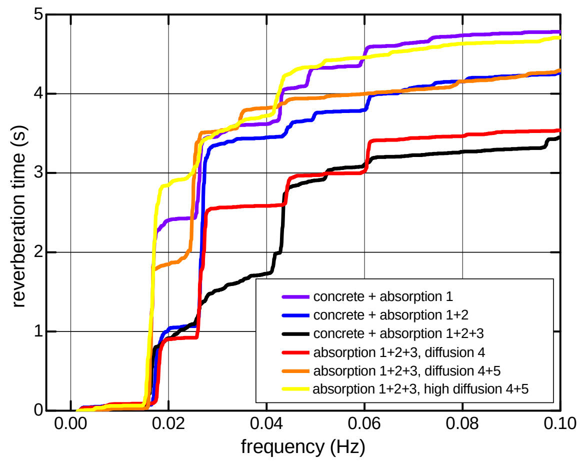

Fig.7 The cumulative gain for three central octaves measured with a sound source positioned at the point B and the receiver at point 2.

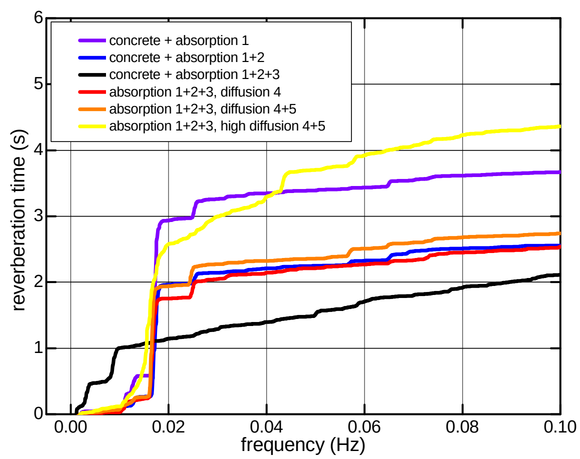

Fig.8 The cumulative gain for octave at 2 kHz measured with a sound source positioned at the point B and the receiver at point 4.

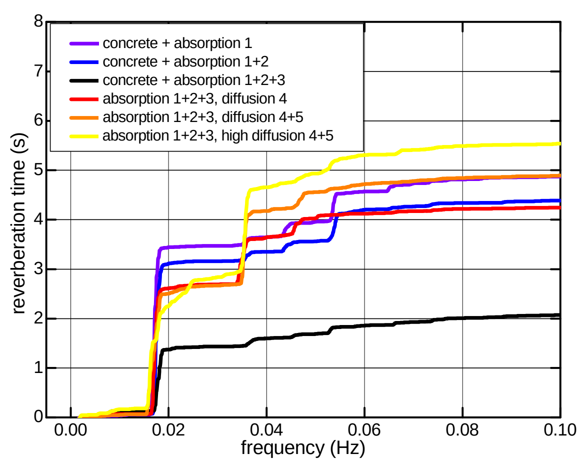

Fig.9 The cumulative gain for octave at 2 kHz measured with a sound source positioned at the point B and the receiver at point 5.

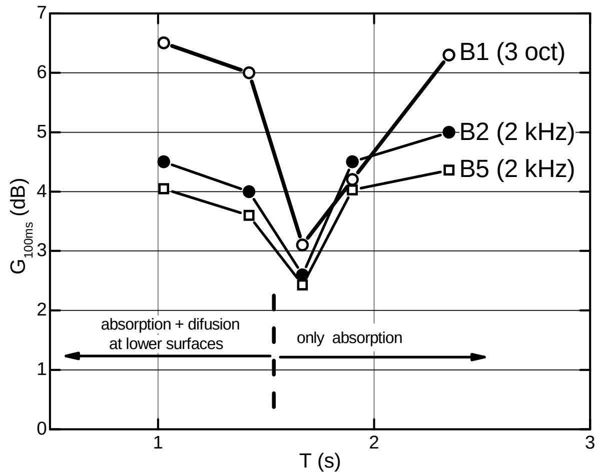

Fig.10 Three examples of gain variation as a function of reverberation time in the hall

3. CONCLUSION

The hall of National Theatre in Subotica, which is at this time under construction, represents a good example of modern needs concerning the venues for drama performances and their aesthetics. Analysis based on measurement in the scaled model of the hall have showed that there are prospective way to merge the unusual demands of theater hall contemporary design, on the one side, and the requirements of the acoustics which implies good audibility of sounds and intelligibility of speech, on the other side. The results presented in this paper show that solutions should be considered an an adequate combination of absorption and scattering within the given interior of the hall. It is important that the diffusivity, a relief, in practice can be carried out with any hard material, as well as concrete. Thus, the request for visible concrete surfaces in the hall is not contradictory with the acoustical design needs. There remains a significant degree of freedom in the implementation of the relief forms and even using the elements of technology such as technical galleries and the like.

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