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Acoustic aspects of the Lviv Theatre of Opera and Ballet auditory usage

Introduction

For over one hundred years, the Lviv Opera (Ukraine) has been intensely used for theater, opera and ballet performances. Performers appreciate its interior for its exquisite appearance which is the result of great design and rich decorations as well as acoustics which make it possible for the sound to be heard very well both in the auditorium and on stage. Due to the building's technical deterioration, it was necessary to renovate it and restore some of the elements of its decor and consequently its original splendor. The modernization which was conduced in the 1980s was not positively received by the performers as the building's interior acoustics for symphonic music decreased. In order to avoid the same mistakes during the modernization of the hall in 2008, the authors of this paper were asked for acoustical consultations. As a result of detailed tests and analyses it was possible to maintain the acoustic features of the theater.

Description of the building

Lviv State Academic Opera and Ballet Theatre of Solomiya Krushelnitska (Lviv Opera) is a special building, very important for Lviv architecture and culture. It was designed by Zygmunt Gorgolewski – one of the best architects at that time (Fig. 1, p. 246). The construction works, which were supervised by Gorgolewski, lasted for three years [9]. The City Theater in Lviv was built during the theater construction boom in Europe. It demonstrates a synthesis of the achievements in theater architecture and technology. The grand opening night was on October 4, 1900 with great guests such as directors of the most famous European theaters and a lot of artists.

The theater features the Italian Renaissance details with classicistic elements [3, 10]. The Opera's auditorium has 4374 m^3 and 1050 seats. The stage section is equipped with advanced technology with moving platforms (hydraulic elements were manufactured by Polish railroad factory in Sanok).

Over the last few years, after a period of neglect, the building has been successively renovated and its original magnificent auditorium has been restored with the use of modern technology. In 1980, the first modernization was conducted. It included a replacement of the metal construction of the floor with concrete floor covered with pinewood boards on joists (Fig. 2, p. 246). At that time the boxes were decorated with lambrequins, which negatively affected the acoustics of the hall. Artists complained that the voice and music performed in the theater sounded more dull, which was caused by an increased absorption of high frequencies by soft elements. Due to the lack of acoustic documentation from that time it is impossible to objectively determine the impact of the first renovation on the interior acoustics. In order to eliminate the possibility of negative impact of the next modernization on the acoustics, their test was commissioned before the commencement of the renovation. The replacement of floors and renovation of the interior was scheduled to be conducted during the summer break in 2008 [8].

In order to maintain the acoustic parameters of the renovated hall, acoustic tests were conducted before modernization to determine a frame of reference as well as the parame-

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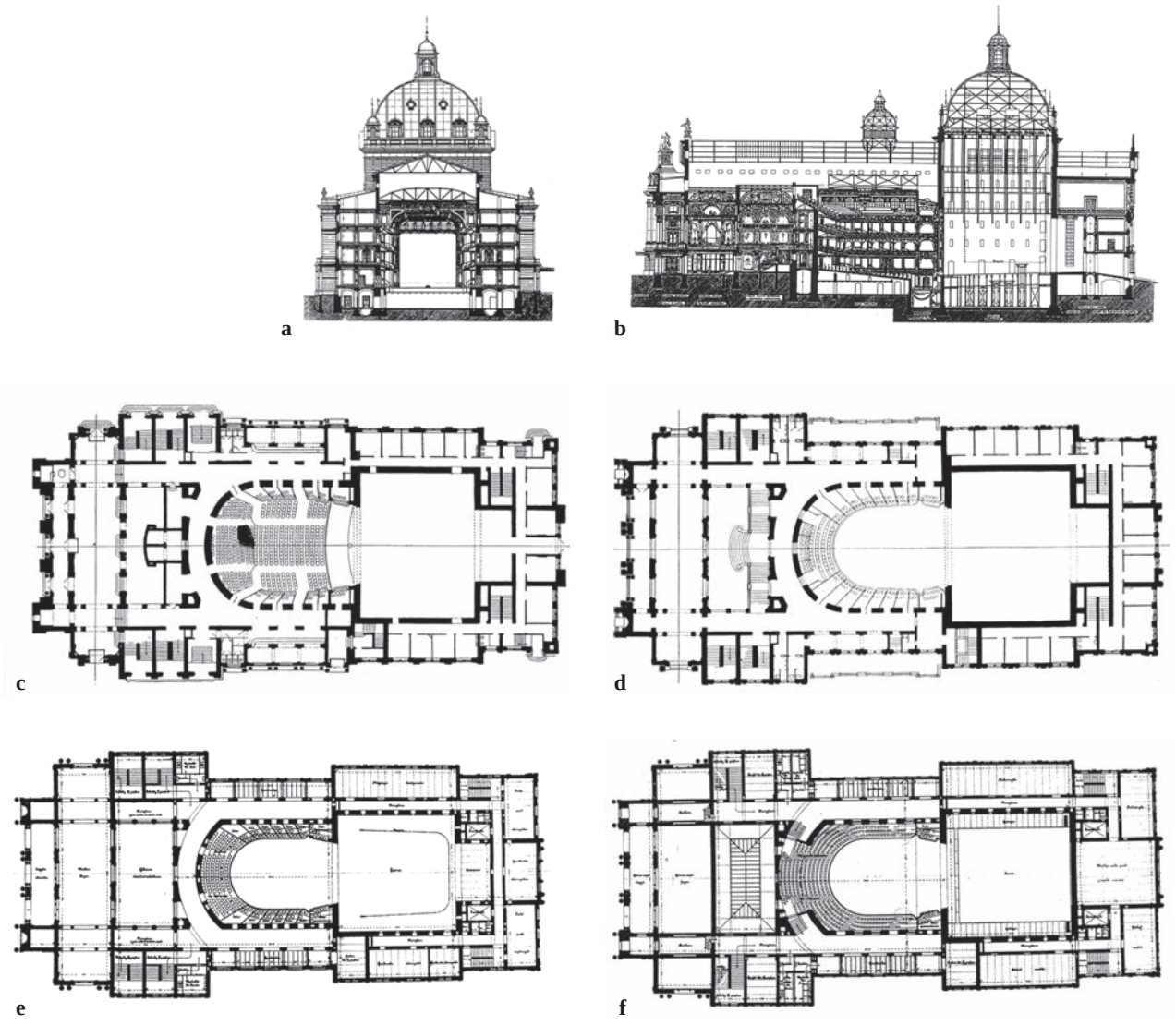

Fig. 1. Sections and plans of individual floors of the theater [9]: a) cross section; b) longitudinal section; c) ground floor plan; d) first floor plan; e) second floor plan; f) third floor plan

Fig. 2. Replacement of floor construction in 1980: a) view of disassembled floor construction; b) floor construction metal I beams

Fig. 3. Replacement of floor construction in 2008:
a) floor joists placed on reinforced concrete floor; b) parquet floor boards on plywood and joists

ters which as requested by the investor should be maintained. Laboratory tests of the selected interior decor elements to be replaced such as floor boards, carpets, and lambrequins were done. Important tests included the measurements of dynamic properties of floor samples with different layers. The natural frequencies of the floor layers were measured and the floor assembly method assuring the best sound-absorbing qualities was specified [5]. It was found that the solution planned by the investor, consisting in laying oak parquet on pinewood boards would decrease the acoustics of the hall. It was suggested that the boards be replaced with thin plywood, decreasing the gap between parquet and the reinforced concrete slab and sound dispensers be installed on the back wall of the cavity under the balcony [7].

Test of the hall's acoustics

The modernization of the hall included among others a replacement of the structure of the floor, armchair upholstery, lambrequins, carpets and renovation of interior decor elements. The works regarded the key elements creating the acoustic fields of the Theater so they needed to be designed in such a way as to improve the acoustic parameters of the interior.

In order to establish a frame of reference for possible changes in the acoustics, acoustic measurements of the hall were conducted in its original condition [4]. By selecting the sound absorption coefficients corresponding to the materials used in the hall a model was adapted to the acoustic compliance with the results of the tests in the scope of selected acoustic parameters (T_{30} and T_{15}). A simulation was made with the use of CATT-Acoustic v.8.h computer program.

Analysis of the diagram in Fig. 4a demonstrates that the reverberation time characteristics have not significantly changed after the renovation, however, the slight differences which have been detected between the characteristics are within expected tolerance. The correct selection and application of the floor layers, carpets and lambrequins had the most evident influence on the maintenance of the original acoustics of the hall after modernization. The values measured before and after modernization as well as the results of the simulation of the parameters are very similar

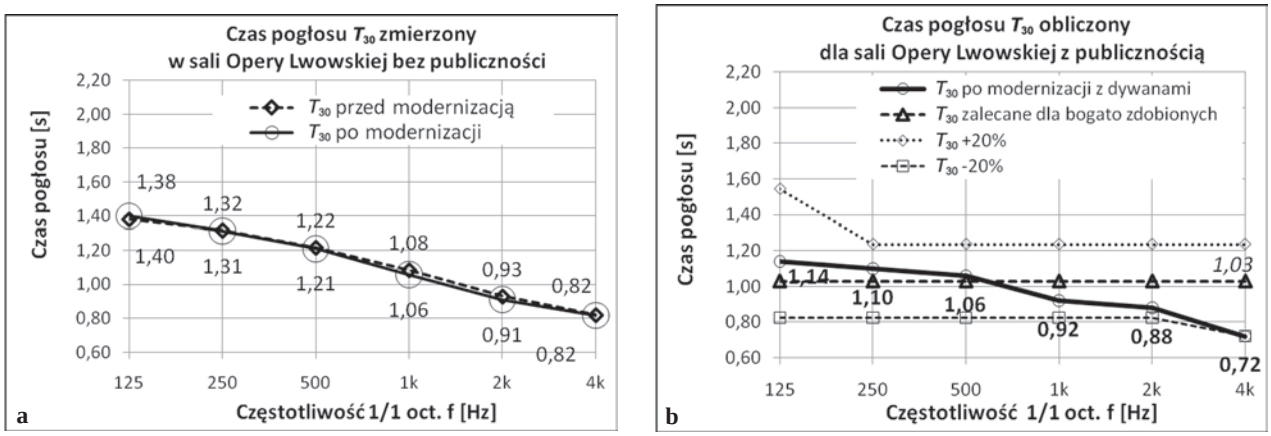

Fig. 4. The Lviv Opera – real and simulated average value of the reverberation time T_{30} depending on frequency:
a) measured; b) from computer simulation

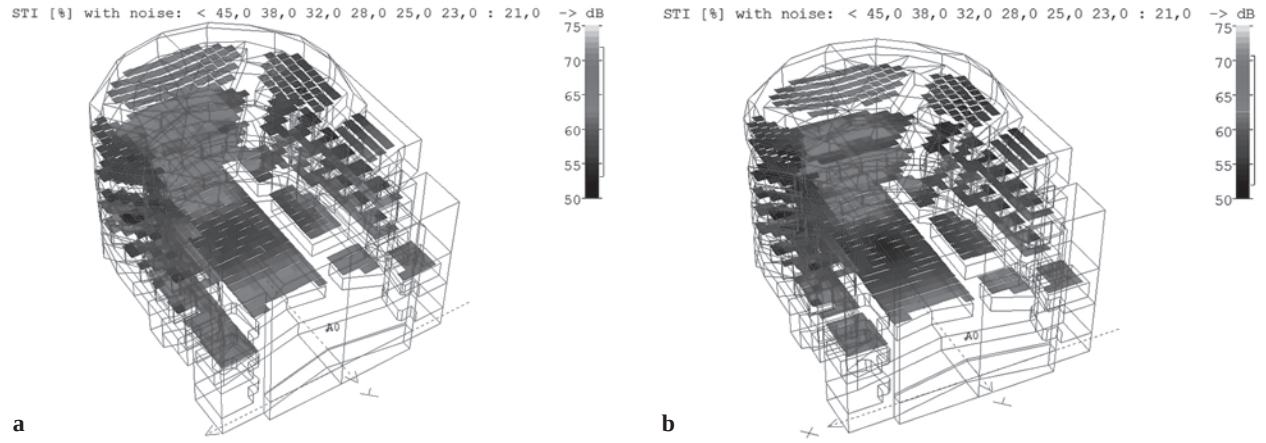

Fig. 5. The Lviv Opera. Computer simulated distribution of STI parameter in the auditorium (without audience): a) before modernization, b) after modernization

and they fall within the scope marked in Fig. 4b. of the values recommended for opera halls, so it was possible to assume that the acoustics of the renovated interior would be positively received by the performers and listeners. The measurements conducted after modernization confirmed the correct selection of new materials and the compliance of the numerical model with reality. The positive reception of the acoustics of the renovated interior by the performers and listeners enabled the final determination of the correctness of the measurements and the simulation.

It should be noted that the shape of the reverberation time characteristics in opera halls should be as close as possible to the horizontal line [1] and [2] so all design and execution activities were aimed at achieving these parameters. In this context it should be also noted that all soft elements additionally introduced to the auditorium space adversely affect the characteristics to decline more. The authors suggested to the investor eliminating the lambrequins and the carpets from the auditorium space to extend the reverberation time to high frequencies. However, the activities aimed at improving the acoustics of the hall were not in line with the conception of the interior decor and they were rejected. After the analysis of the tests, a replacement of sound-absorbing with sound-dispersing material in the cavities under balconies and boxes was suggested in order to additionally improve the acoustic parameters of the whole hall.

Figure 4 shows the real/measured (4a) and computer simulated (4b) average values of the reverberation time T30 for the auditorium of the Opera. Fig. 4b shows also the method of assessment of the reverberation time characteristics developed for the opera interiors with rich decorations [6]. The theater interiors designed on a horseshoe plan with carpets, lambrequins and rich upholstery demonstrate shorter reverberation time than it is assumed in literature for theaters. Figure 5 shows a simulated distribution of STI parameter in the auditorium before and after modernization. An improvement of the speech transmission quality in the middle section of the auditorium on the ground floor is evident. A decisive majority of the seats in the auditorium has STI parameter within the scope of good speech transmission.

Final notes

The natural acoustics are extremely important in every concert hall, opera or theater. Poor audibility makes it difficult for the performers to perform and for the listeners to enjoy listening. That is why if the acoustics of any interior co-create the artistic message, it should be considered a priority. As a result of great commitment of the management of the Lviv Theater, it was possible to appropriately execute the modernization. The acoustic tests before and after modernization as well as the model and simulated tests enabled the determination of reference conditions and specification of the objective to be achieved. With the use of multi-variant simulations, measurements and precise workmanship, it was possible to achieve the assumed acoustic conditions. The objective measurements were supported by a positive reception among the performers and listeners, which confirms their reliability. Further improvement of the acoustics by eliminating soft elements is impossible, and that is why cladding the back wall with sound-dispersing materials was suggested in order to improve the audibility in the section of the auditorium under the balconies.

Acknowledgments

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Aspekty akustyczne użytkowania sali widowiskowej opery we Lwowie

Lwowski Narodowy Akademicki Teatr Opery i Baletu im. Salomei Kruszelnickiej jest szczególną budowlą, zajmującą ważne miejsce w architekturze i kulturze Lwowa. Obiekt zbudowany w 1900 roku zaprojektował Zygmunt Gorgolewski, jeden z najwybitniejszych ówczesnych architektów. Widownia posiada kubaturę 4374 m^3 i mieści 998 osób. Budynek jest sukcesywnie remontowany, zaś sala jest doprowadzana do pierwotnej świetności. W celu zachowania parametrów akustycznych sali, w trakcie prac modernizacyjnych prowadzono bieżące ekspertyzy akustyczne. Przeprowadzono wymianę podłóg i elementów wystroju wnętrza. W celu zachowania parametrów akustycznych remontowanej sali wykonano badania laboratoryjne wybranych materiałów wystroju, takich jak: deski, dywany, lambrekiny i elementy tapicerki. Wykonano również badania akustyczne sali widowiskowej przed wykonaniem prac renowacyjnych, w trakcie oraz po zakończeniu. Po analizie badań można stwierdzić, że charakterystyka czasu pogłosu po remoncie nie uległa istotnym zmianom. Zwrócono uwagę na wnęki podbalkonowe parteru i loże, gdzie istniałaby możliwość zamiany wybranych okładzin dźwiękochłonnych na rozpraszające, co korzystnie wpłynie na wybrane parametry akustyczne sali.

Key words: Lviv, opera house, acoustic aspects

Słowa kluczowe: Lwów, opera, akustyka