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THE INFLUENCE OF NEW MATERIAL TECHNOLOGY ON ACOUSTIC TREATMENT OF MODERNIZED INTERIORS

WPŁYW NOWYCH TECHNOLOGII MATERIAŁOWYCH NA ADAPTACJĘ AKUSTYCZNĄ MODERNIZOWANYCH WNĘTRZ

Abstract

The paper deals with the problem of the acoustic treatment using modern material technology in the modernization of old interiors. On the example of an auditorium with approved acoustics, that was built in 1962 and is located at the Lviv Polytechnic, some important directions in handling this type of object was shown. The acoustic measurements of the room showed, that structures used in the 60s are acoustically proper, but planned renovation should be based on modern technologies.

Keywords: acoustics, speech intelligibility STI, reverberation time, Lviv Polytechnic

Streszczenie

W artykule podjęto zagadnienia modernizacji wnętrz o uznanej akustyce z użyciem współczesnych materiałów. Jako przykład wybrano przygotowywaną do remontu salę audytoryjną Politechniki Lwowskiej (bud. 1962). Przeprowadzone badania akustyczne wykazały poprawność istniejących rozwiązań, jednak projektowane zmiany muszą opierać się na współczesnych technologiach posiadających odmienne właściwości.

Słowa kluczowe: zrozumiałość mowy STI, czas pogłosu, Politechnika Lwowska

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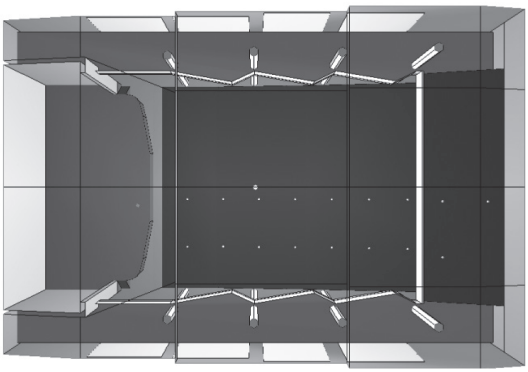
1. Introduction

The main goal of the paper is to analyze the influence of materials and technology used in the acoustic treatment of interiors, that were used in the 60s of the XX century and those used nowadays. The research was made in a multi-purpose room built in 1962 and owned by Lviv Polytechnic. The room is used mainly as an auditorium for 800 people. It is a classical shoe-box in shape with dimensions of 35.5 × 24.0 × 9.7 m (Ill. 1a, b). The volume of the room is about 6100 m^3. At the rear wall of the room and along the side walls, there is a balcony. The side walls on the lower level (below the balcony) consist mainly of windows. Above, there are balcony railings and again windows. The auditorium consist of benches and chairs made of laminated plywood. On the ground floor, in the part closer to the stage, the auditorium is flat, while beginning from the middle of the room, the floor is sloped. That profile of the auditorium provides proper sight and listening conditions even in the most distant rows. Moreover, this type of floor limits the area of the back wall of the room, which reduces the possibility of an acoustic flow (like an echo) to occur. The ceiling was shaped in a specific way to provide proper transmission of sound to the most distant rows of the room and to

a)

b)



Ill. 1 a) Picture of the analyzed room, b) Visualization of the room in CATT-Acoustic software the balcony; however, perforated steel plates used there and characterized by high sound absorption in the wide frequency band, reduce the effectiveness of the ceiling.

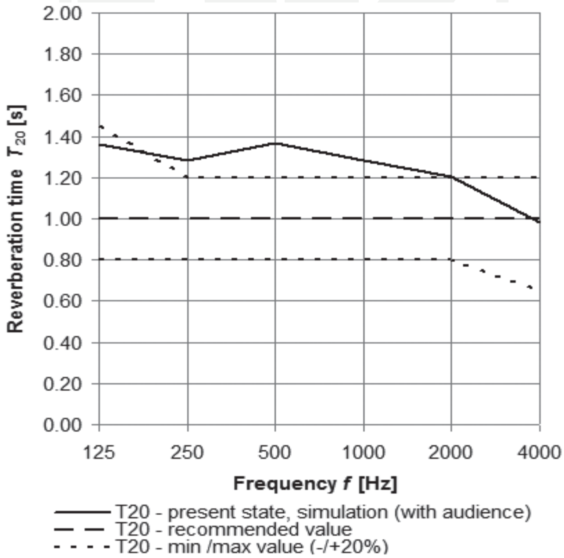
2. The measurement and analysis of the selected acoustic parameters

For the auditorium, which is made for verbal communication, the most important parameter is speech intelligibility, so in the further analysis, the Speech Transmission Index was investigated. The maximum value of STI is 1 (the best intelligibility) while the minimum is 0. Moreover, the reverberation time T_{20} was measured and calculated as the most important acoustic parameter of each interior.

The present acoustic conditions of the room were measured based on standard procedure [1]. It should be noted, that during measurement, the auditorium was without audience. Introducing listeners into the room has a great impact on the room's total absorption [2], which influences the reverberation time and speech intelligibility. That is why the evaluation of the room is always made for the room with an audience. In order to calculate the acoustic parameters of the room with people, there was an acoustic model made in CATT-Acoustic software [3, 4].

The input parameters of the model was the geometry of the room obtained from its technical documentation, the sound absorption and scattering coefficients of the materials used in the interior. The model was validated based on the measured reverberation time in the room.

The evaluation of the acoustic parameters based on the results of measurements and numerical simulation showed that the reverberation time for different frequencies are comparable for low and mid frequency range, while the average value of reverberation time is equal to T_m = 1.33 s, which is slightly more than recommended for that type of room (Ill. 2)



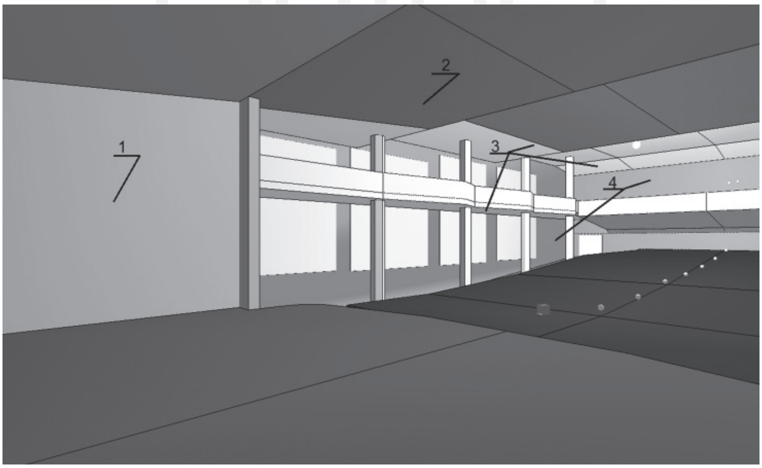
Ill. 2. The evaluation of the reverberation time frequency characteristic of the auditorium filled with listeners. The values were calculated in the CATT-Acoustic software

According to the recommendation of Rettinger [5], it was assumed that for the 6100 m^3 auditorium with an audience, the reverberation time should be equal to T_m = 1.00 s. Calculated values of the Speech Transmission Index for the room with an audience are between 0.56–0.69, with an average value of 0.61. This means, that speech intelligibility for the audience in most of the area is good. Only in the middle of the room, are there lower values of STI, where the speech intelligibility is average.

3. The design of the modernization of the room using new material technology

The aim of the analysis was to formulate acoustic guidelines for the project of auditorium modernization. The main assumption was to reduce the reverberation time to the values recommended in the literature (T_m = 1.00 s) and to improve speech intelligibility. Because of the fire protection and inaccessibility of the original materials used in the interior, the new acoustic treatment was based on modern material technology.

Based on the numerical model, several computer simulations of the acoustics inside the room were made, which led to proper material selection and the proposition of their optimal placement. Thanks to that calculation, it was possible to obtain the best possible acoustic parameters in the room. Details of the arrangement of materials inside the room and their acoustic proprieties are shown in the Ill. 3 and Tab. 1.



Ill. 3. Arrangement of new materials inside the auditorium

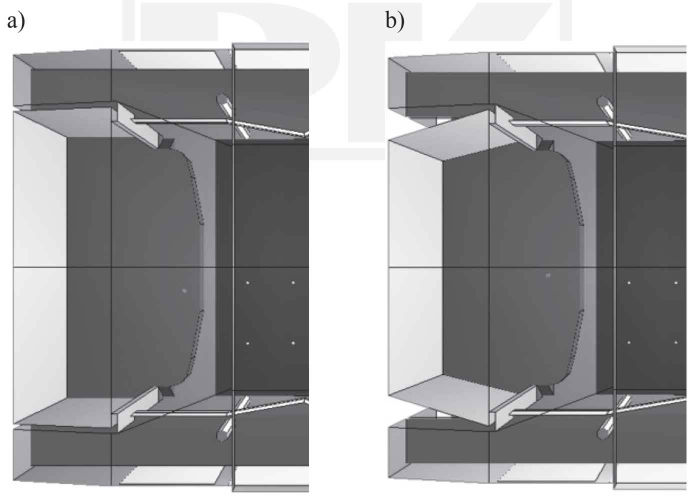
The selected project of acoustic treatment, proposed the replacement of the ceiling finishing material. Perforated steel plates should be replaced by perforated gypsum boards and a stone or glass wool acoustic ceiling. As it was shown in the literature [6], the sound reflected from the ceiling to the listeners has an enormous meaning in the reception of the acoustic quality of a room. That is why a lot of work was made during the designing of the ceiling in the described room.

On the available surfaces of the rear wall below, on the balcony and on the side walls below the windows, perforated gypsum-fiber plates should be used. The sound absorption coefficient of all new materials used in room are presented in Table 1.

Table 1

Sound absorption coefficient of materials used in the acoustic treatment of the room

No.	Material description	Sound absorption coefficient α					
		125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
1	Laminated gypsum-fiber plate, 30 mm, ODS = 62.5 mm	0.11	0.04	0.03	0.03	0.04	0.05
	Gypsum board with grouped square perforation and acoustic coating at rear, ODS = 62.5 mm	0.45	0.50	0.45	0.35	0.30	0.30
3	Glass wool acoustic ceiling, ODS = 200 mm	0.50	0.75	0.80	0.95	0.95	0.95
4	Laminated gypsum-fiber plates with round perforation, ϕ8 mm, mineral wool 30mm, ODS = 62.5 mm	0.37	0.80	0.99	0.90	0.70	0.57

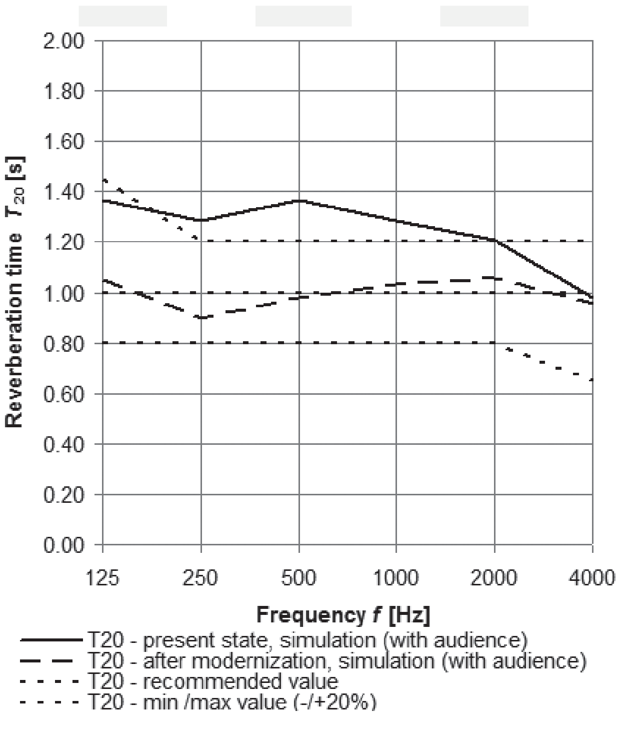


Ill. 4. The correction of the side and rear wall of the stage

In the scope of the modernization of the room, the stage was completely rearranged. Curtains hanging on the stage were replaced with gypsum-fiber plates and the geometry of the stage's side walls was changed to provide better sound transmission to the audience (Ill. 4).

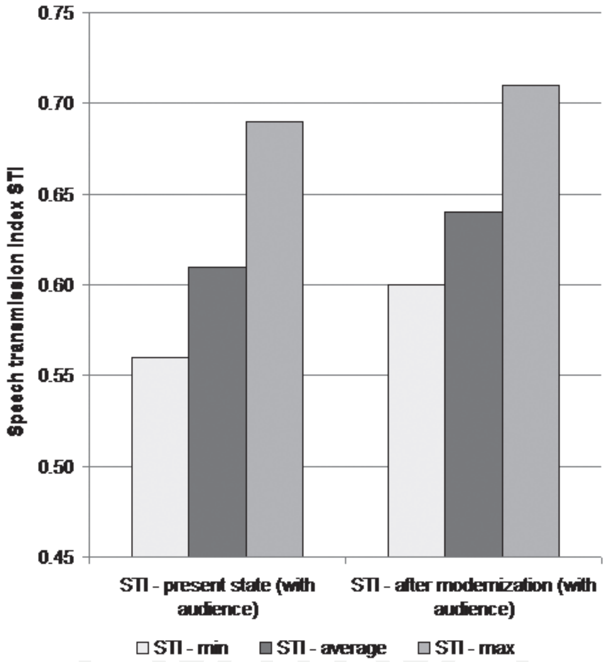
This solution will also eliminate the flutter echo on the stage. Moreover, putting sound reflector arrays above the stage was considered to shorten the initial time delay gap (time between the direct sound and the first reflection) [7, 8], but this solution was rejected by the architect.

For the selected acoustic treatment of the auditorium, acoustic simulations were made. Comparison of frequency characteristics of reverberation time in the present state and after modernization is shown in Ill. 5. One can see that the new treatment reduced reverberation time; the average value for 500 and 1000 Hz frequency band after modernization will be 1.01 s instead of 1.33 s in the present state. Moreover, the reverberation time for every frequency band will be almost equal especially for mid and high frequencies. Reduction of reverberation time is an effect of increased absorption of the wall, especially at the rear of the room. Shorter reverberation time will provide better speech intelligibility, listening conditions and the general comfort in using the room.



Ill. 5. Comparison of reverberation time before and after modernization of Lviv Polytechnic auditorium. Results according to CATT-Acoustic software

Numerical calculation of speech transmission index showed that for selected solutions of acoustic treatment, STI will be higher that in the present state. Obtained values are in the range of 0.60–0.71, with an average value of 0.64. This means, that in the whole audience area, the speech intelligibility will be good.



Ill. 6. Comparison of speech transmission index STI before and after modernization. Results acc. to CATT-Acoustic software

4. Conclusions

The analysis of acoustic parameters in the present state of Lviv Polytechnic auditorium built in the 60s of the last century show, that the room has an excessively long reverberation time according to the literature recommendation. On the other hand, flat frequency characteristics of reverberation time provide good speech intelligibility in most parts of the audience.

Because of the planned renovation of the room, multi-optional simulation of acoustic parameters in CATT-Acoustic software were made. Several different solutions were considered based on new material technologies. Selected acoustic treatment will reduce reverberation time and improve sound transmission from the stage to the audience. Reducing reverberation time was possible because of higher acoustic absorption of the wall at the rear and side part of the ceiling, rear wall and ceiling above the balconies. High absorption in the wide frequency band will be obtained by an acoustic ceiling made of glass wool. Better sound transmission to the rear of the room will be provided because of the replacement of perforated steel plates by carefully selected perforated gypsum-board. The new materials used in the project of the stage will have a great impact on the sound transmission, especially to the places below balconies [9]. Because of the changed geometry of the stage, it will be free from acoustic faults like flutter-echo.

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