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EFFECT OF REVERBERATION ON SPEECH INTELLIGIBILITY, LOGATOM TEST "IN SITU"

WPŁYW POGŁOSU NA ZROZUMIAŁOŚĆ MOWY, BADANIA LOGATOMOWE „IN SITU"

A b s t r a c t

The influence of acoustic parameters of lecture halls is essential for the quality of reception and the understanding of the content. One of the basic acoustic parameters is the reverberation time in the room. The study demonstrates that the room which is not properly designed for acoustics, causes difficulty in understanding the delivered text. Selected acoustic parameters were analyzed, such as reverberation time, acoustic background, and delivered text intelligibility. A possible solution was proposed, using reflecting and absorbing surfaces appropriately positioned in the room.

Keywords: acoustics, reverberation time, logatom test, quality of teaching

S t r e s z c z e n i e

Wpływ parametrów akustycznych sal, w których odbywają się wykłady, ma zasadnicze znaczenie dla jakości odbioru i zrozumienia treści. Jednym z podstawowych parametrów akustycznych jest czas pogłosu pomieszczenia. W pracy wykazano, iż sala nie będąca odpowiednio zaprojektowana pod kątem akustyki powoduje trudności w zrozumieniu wygłaszanego tekstu. Analizowano wybrane parametry akustyczne, takie jak: czas pogłosu, tło akustyczne, zrozumiałość czytanego tekstu. Zaproponowano dopuszczalne rozwiązanie przy zastosowaniu powierzchni odbijających i pochłaniających odpowiednio usytuowanych w pomieszczeniu.

Słowa kluczowe: akustyka wnętrz, czas pogłosu, logatomowy test, jakość nauczania

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Designations

V	–	total volume of the room [m^3]
S	–	total surface of the faces limiting the room [m^2]
Sx, Sy, Sz	–	total surface perpendicular to the axes
$\alpha śr$	–	average sound absorption coefficient [m^2]
$\alpha śr.x$, $\alpha śr.y$, $\alpha śr.z$	–	average sound absorption coefficient in the direction of the axes
α	–	Fitzroy-sound absorption Fitzroy coefficient,
f	–	frequency [Hz]
T	–	reverberation time [s]

1. Introduction

The influence of acoustic parameters of the halls where lectures are held, is essential for the quality of reception and understanding of the content, and for listeners' concentration [1–5, 8]. One of the basic parameters is the reverberation time in the room [6, 7]. The reason for choosing this particular topic in the field of acoustics, was the concentration difficulties of students during long speeches and lectures held all day, due to designers' and users' ignorance in the field of acoustics, which negatively impacted the teaching effects.

2. The subject of investment

The investment subject is a project of acoustic adaptation for the room 209H in the "Houston" building of Cracow University of Technology. It is a hall which hosts lectures and presentations. The room is a cuboid of a rectangular base, it is long and relatively narrow, the outer wall is covered with windows. The room is located on the second floor of the building, there are similar classrooms above it and below it, and it is separated from the hallway by wooden door and from the outside by PVC windows.

3. Measuring devices and methods and calculation methods.

According to the [1, 4–7, 11] are used formulas: Sabine, Fitzroy, Eyring (formula 1) as below:

$$T_{60.\text{Fitzroy}} = (0.161*V)/(S*\alpha_{\text{Fitzroy}})\ \alpha_{\text{Fitzroy}} = -S*(S_x/\ln(1-\alpha_x) + S_y/\ln(1-\alpha_y) + S_z/\ln(1-\alpha_z))$$

$$T_{60.\text{Sabine}} = (0.161*V)/(S*\alpha_{\text{śr}})\ T_{60.\text{Eyring}} = (0.161*V)/(-S*\ln(1-\alpha_{\text{śr}})) \quad (1)$$

After the analysis [7–11], a range of measuring instruments and methods led to the use of simple methods and basic measuring equipment. Mobile phone – with integrated microphone (used for the initial analysis) with frequency: 20 Hz ~ 20 kHz, frequency range –6 dB, THD+N (total harmonic distortion plus noise) 1.0% ± 0.2%, high sensitivity – up to 10 m, sensitivity of the comparative microphone 2 mV/Pa. Sound level meter – a device with a sensitive microphone, used to measure the background noise and reverberation time. The sensitivity of the loudspeaker SPL 2.83 V/1m 1 W was 94 dB. The meter gives the volume in dB. In background noise measurements an A-weighting was used. The study for speech intelligibility was carried out using the logatom test [12].

Logatom test was developed in accordance with [12–14]. Example of logatom is illustrated in Fig. 1.

dufcze	cze	teń	jo	czalmy	chfypa	dy	pa	gruto	słynej
ajtes	wać	foli	es	ny	ca	zjaiech	piestma	ke	jentuś
Wesk	niacko	delak	gapysz	nij	czniesa	wyzo	fa	todzi	jos
Pi	wespa	szo	tyr	dnaf	szaźmo	żam	żnota	ply	bep

Fig. 1. Part of 100-logatom list for the Polish language

4. Results

The results of the in situ reverberation time measurements and calculations are shown in Fig. 1. The results of logatom test are shown in Fig. 2. The study (for logatom test) was carried out successively at 9.15 am, 10.40 am, 12.20 pm, 6.00 pm. The graph shows the results of the three measurements, due to the fact that one of the tests was considered to be invalid.

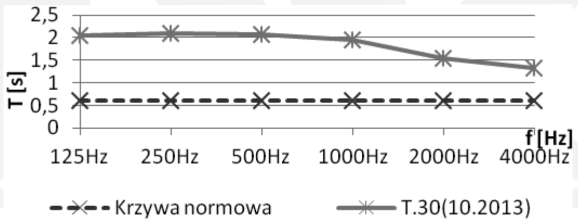

Fig. 2. Measured reverberation time

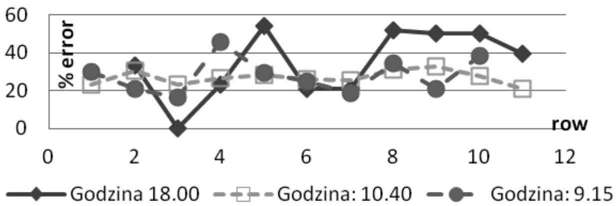

Fig. 3. Intelligibility test: the error % to row number

5. Analysis of the results

In terms of 1000 <f> 4000 Hz, both in May and October, the reverberation time was in the range 1,55–1,33 s. It corresponds to a value of preferred in sites such as an opera hall. In terms of 125 to 1000 Hz, the measured reverberation time was 2,34–1,95 s. This value exceeded the value preferred even for concert halls. The results of logatom test: in the morning on average 25–38% of the students made mistakes. In the afternoon percent of errors ranged from 40 to 58. This means that more than half of the students did not understand more than half of the content of the lecture. The worst speech intelligibility showed in the research is for rows 5 and 8, and the effect of time of day on the logatom test results is noticeable (Fig. 2). The results: auditorium can be classified into groups of rooms that require the improvement of acoustics.

6. Acoustic adaptation

In order to obtain better acoustic parameters, the use of materials was proposed as follows: the ceiling – 60 m^2 of drywall and 20 m^2 of Ecophon Master Rigid, plus two Extra Bass panels; the side wall with the door – 25 m^{2}of drywall and 12 m^2 of Rockfon Verti *Q* as one strip alongside the ceiling; the back wall – 15 m^2 of Rockfon Verti *Q* (on both, opposite side wall). The proposed arrangement is shown on the next page (Fig. 4). The calculation result of future application of these materials is shown in the Fig. 3 and, because not always all the seats are occupied in the classroom, an additional analysis with 50% of seats being occupied (Fig. 5) was carried out. The results of theoretical calculations (reverberation time 0,49–0,59 s) correspond to the values preferred for voice-recording studio (reverberation time of 0.3–0.5 s) and did not exceeded the normalized value (Fig. 3, 5).

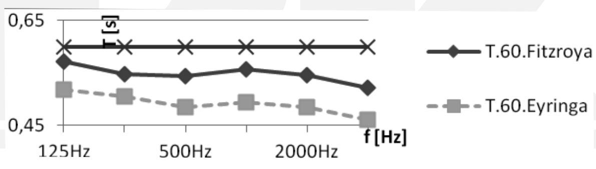

Fig. 4. Reverberation time after acoustic adaptation

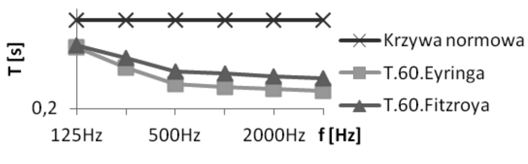

Fig. 5. Reverberation time after acoustic adaptation
for 50% of seats being occupied

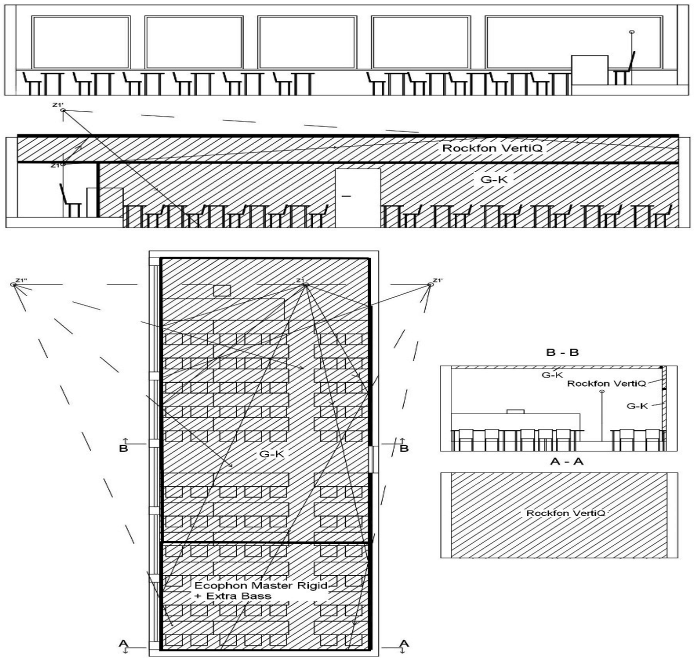

Fig. 6. Design of arranging acoustic materials. Z1 – the source of sound

7. Conclusions

It seems that, at the stage of preliminary assessment of acoustic lecture halls (without the need for lengthy and complicated measurements), measuring two basic parameters such as reverberation and speech understanding as a logatom study, is sufficient in the two cases. First: their categorization. Second: the decision what kind of material should be applied to improve the quality of understanding. However, in order to obtain precise results one should run more tests with a constant number of students in each group. it may depend on the location of the door, which carried the sounds of the corridor (in this case study). Use of the logatom test to assess the acoustic quality of rooms is a very good method. It allows us, under real conditions, to check the actual ability of listeners to understand the transmitted content. Even more importantly, in classrooms the teaching effect directly depends on understanding the teacher's speech, and this directly and strongly depends on the reverberation time. Before the acoustic-renovation of the auditorium, the logatom test should be repeated using an intelligibility measurement method in rooms (classrooms) together with its automated version called modified intelligibility test with forced choice (MIT-FC), according to the [15] measurement, and subsequently compared with previous research. After the acoustic-renovation of the auditorium, in order to assess the actual effect, a control logatom test according to the [15] must be carried out.

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