

EXPERIMENTAL STUDY OF ACOUSTIC PROPERTIES OF INTERIOR FACING PANELS

SUMMARY

This paper presents a study on the sound absorption reverberation coefficient of Fermacell RIGIPS gypsum facing panels. The facing panels showed a high value of the sound absorption coefficient for frequencies below 200 Hz. A study was also undertaken on methods for reducing the multiple echo. The dependence of the multiple echo decay on the angle of deviation from parallel arrangement of walls was determined. Also studied was the effect of the room's acoustic absorptivity on the identifiability of the multiple echo. The study has demonstrated usefulness of commonly available wall facing in the design of acoustic system capable of significantly reducing most frequent acoustic defects of rooms.

Keywords: multiple echo, reverberation time, facing panels, sound absorptivity

BADANIA DOŚWIADCZALNE WŁASNOŚCI AKUSTYCZNYCH OKŁADZIN PŁYTOWYCH STOSOWANYCH WE WNĘTRZACH

W pracy przedstawiono badania pogłosowego współczynnika pochłaniania dźwięku struktur okładzinowych typu Fermacell oraz typu RIGIPS. Okładziny wykazały dużą wartość współczynnika pochłaniania dźwięku dla zakresu częstotliwości poniżej 200 Hz. Podjęto również badania nad metodami redukcji echa wielokrotnego. Otrzymano zależność zaniku echa wielokrotnego od kąta odchylenia ścian od równoległości. Badano również wpływ chłonności akustycznej pomieszczenia na identyfikację tego zjawiska. Wykazano przydatność ogólnie stosowanych płyt do projektowania ustrojów akustycznych niwelujących najczęściej spotykane wady akustyczne pomieszczeń.

Słowa kluczowe: echo wielokrotne, czas pogłosu, okładziny płytowe, dźwiękochłonność

1. INTRODUCTION

Excessive reverberation in the range of low frequencies and the occurrence of echo, in particular, multiple echo, are the most difficult and, unfortunately, common acoustic defects. Echo is a phenomenon resulting from the time difference between the direct and reflected sounds. The human hearing system can identify delays greater than 50 ms for speech, and greater than 80 ms for music if the signal level above the acoustic background is appropriate. If the delay between the direct and reflected waves is smaller than 50 ms, it produces the impression of an extended sound. This study has demonstrated usefulness of commonly available panels, such as drywalls reinforced with fibre or sandwiched between sheets of paper, in the construction of effective acoustic systems.

2. REDUCTION OF MULTIPLE ECHO RESULTING FROM CHANGES IN THE GEOMETRY OF THE INTERIOR

Multiple echo, also called flutter echo, is a phenomenon involving a sequence of wave reflections between parallel reflexive surfaces. Figure 1 presents examples of geometries favouring the formation of multiple echo.

To investigate this phenomenon, an experiment was planned in a research room of known properties. Figure 2 shows a flow diagram of the experimental set-up located in a 186.1 m³ reverberation chamber (AGH-Cracow), where appropriate conditions were created to study multiple echo. A surface was built from the Fermacell panels so that they could be deviated from their parallel orientation relative to the opposite wall of the chamber.

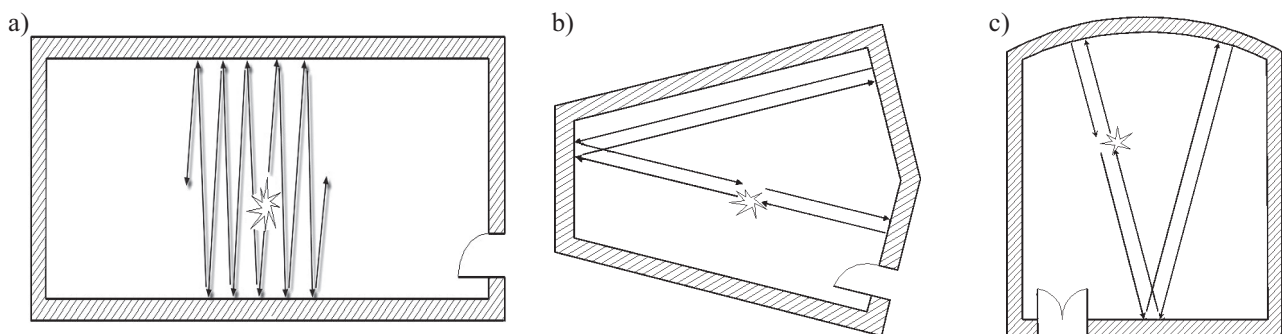


Fig. 1. Parallel walls (a); non-parallel walls (b); a concave-flat wall system (c)

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The chamber's side walls and the floor were lined with glass wool panels and a sound-absorbing ceiling was suspended at a height of 3 m. The acoustic signal was generated with a spark-gap generator or a loudspeaker, and the course of the space's acoustic response was recorded (Fig. 3).

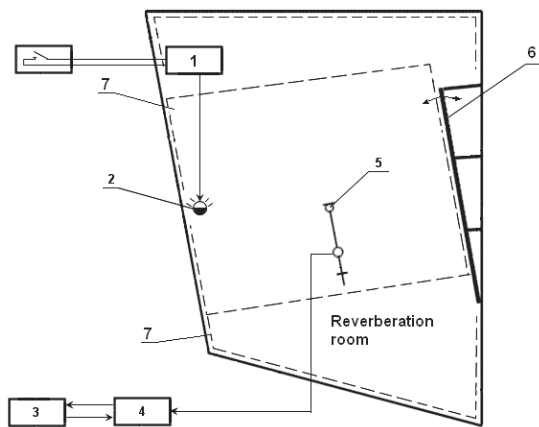


Fig. 2. Schematic diagram of the measurement set-up: 1 – sound source power supply, 2 – electrical spark noise generator or a loudspeaker, 3 – PC computer, 4 – SVAN912A analyzer, 5 – microphone type B&K4133 with tripod, 6 – mobile wall of Fermacell panels, 7 – sound-absorbing material on the floor, ceiling and the wall

By changing the angle of deviation from the parallel wall orientation and registering successive runs, the dependence of multiple echo decay on that angle was determined. As the phenomenon is better observable for a sinusoidal source signal, this case has been described here. To plot the multiple echo decay pattern, the amplitude of the direct wave was compared to those of the second and third reflections A_2/A_0 , A_3/A_0 . The results are shown in Table 1 and in Figure 4.

In the mathematical description of the decay patterns it was assumed that the amplitude ratios A_2/A_0 and A_3/A_0 for an angle of 0° equal 1 (100%), and decrease with an increase in the wall deviation angle (Figs. 4a and b). Microsoft Excel was used to fit the curves with trend lines in the form of second-degree polynomials for which squared correlation coefficient R^2 is the highest.

In order to find, using a subjective method, the deviation angle for which the multiple echo is no longer identifiable, sound samples with recorded impulse responses were listened to. The multiple echo was clearly audible at parallel wall arrangement (0°). By deflecting the wall angle by only 1%, the phenomenon was significantly reduced. The amplitudes of the 2nd and 3rd reflections was then lower by about 11%. At an angle of 5° , the flutter echo was scarcely audible, with the 2nd and 3rd reflection amplitudes of 40% and

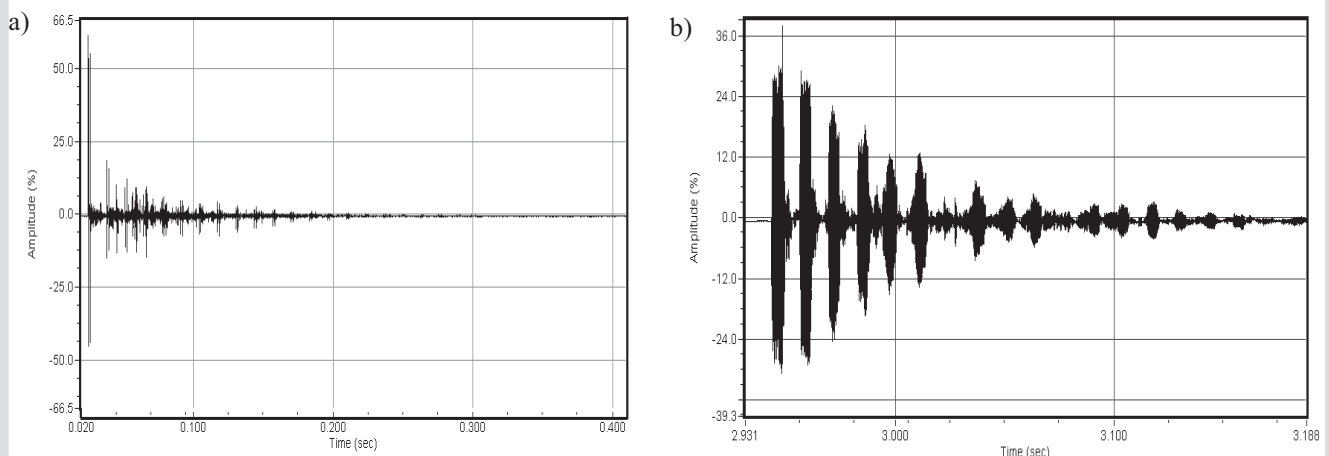


Fig. 3. Response to a pulse generated by a spark-gap generator in a space with parallel orientation of walls (a); room impulse response to a sinusoidal impulse (3802 Hz) for a parallel wall arrangement (b)

Table 1

Wall deviation angle [°]	Direct wave amplitude A_0 [%]	Amplitude of the 2nd reflected wave, A_2 [%]	Amplitude of the 3rd reflected wave A_3 [%]	Amplitude ratio: $A_2/A_0 \cdot 100\%$	Amplitude ratio: $A_3/A_0 \cdot 100\%$
0	28.86	22.07	18.38	77.0	64.1
1	28.83	19.53	16.74	67.7	58.1
2	28.83	14.59	11.4	50.6	39.5
3	28.98	15.02	10.59	51.8	36.5
4	28.91	12.39	8.43	44.4	30.2
5	28.94	10.7	6.93	37.0	23.9
6	28.91	5.37	4.86	18.6	16.8
7	28.97	7.08	6.3	24.4	21.7
8	30.37	6.53	5.54	21.5	18.2
9	29.25	5.36	3	18.3	10.3

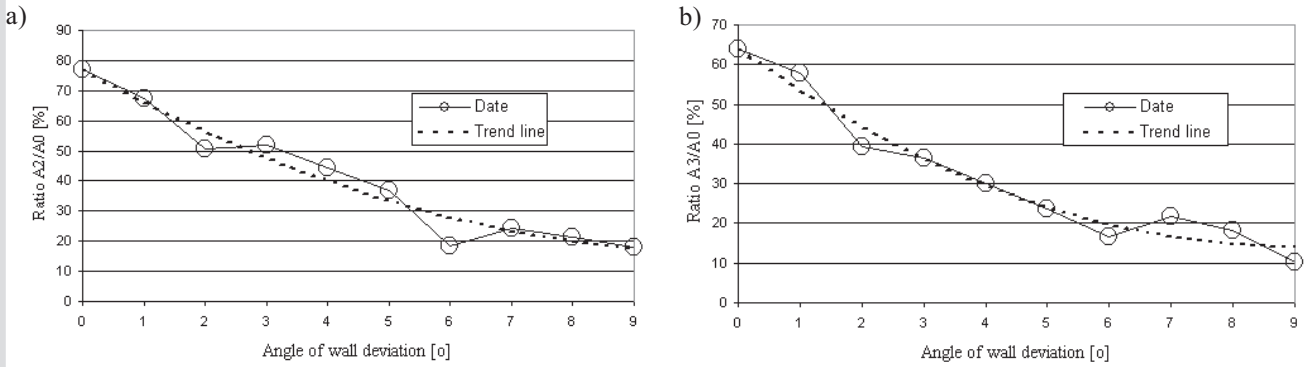


Fig. 4. Dependence of A_2/A_0 on the angle of deviation from the parallel arrangement of walls, examined with a sinusoidal wave source (a); dependence of A_3/A_0 on the angle of deviation from the parallel arrangement of walls, examined with a sinusoidal wave source (b)

44%, respectively. Further reduction in the flutter echo occurred with increasing the angle. After repeated hearings, it was found that for wall deviation angles above 6° , the phenomenon of multiple echo is not identifiable. This provides an important guideline for designers of all spaces intended for people, especially spaces with special acoustic requirements.

3. EFFECT OF ACOUSTIC ABSORPTIVITY OF A SPACE ON IDENTIFICATION OF THE MULTIPLE ECHO PHENOMENON

The effect of the room's acoustic absorption on the ability to identify multiple echo was studied in the measurement stand described above. The experiment consisted in recording the room's impulse responses for varying amounts of sound absorbing material in the chamber. The source signal was pro-

duced by a spark-gap generator. For each variant of filling the chamber with sound absorbing material, with walls arranged in parallel (0°), the reverberation time was measured in accordance with the PN-EN ISO 3382:2001 standard.

Figures 5 through 10 show the experimental results, which demonstrate an essential role of masking in identification of multiple echo. In Figures 5 and 6, successive reflections of the sound wave are distinct, whereas with a further increase in the chamber's reverberation time (Figs. 7 through 9), most of the reflections are masked by the reverberation tail.

Subjective assessment indicates that the multiple echo is not identifiable when the number of noticeable reflections in the echogram decreases by about 50%. In the case of our study this corresponds to the chamber's reverberation time of about 1 s.

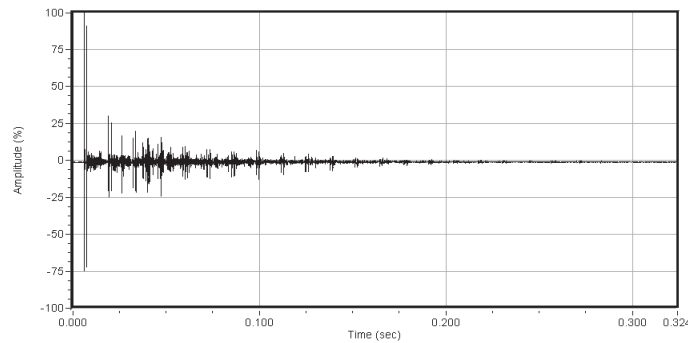


Fig. 5. Room impulse response. Forced by spark-gap generator, wall deviation angle 0° , reverberation time $t_1 = 0.54$ s

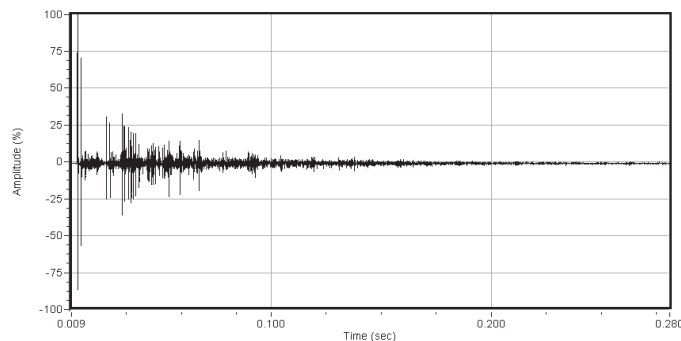


Fig. 6. Room impulse response. Forced by spark-gap generator, wall deviation angle 0° , reverberation time $t_2 = 0.65$ s

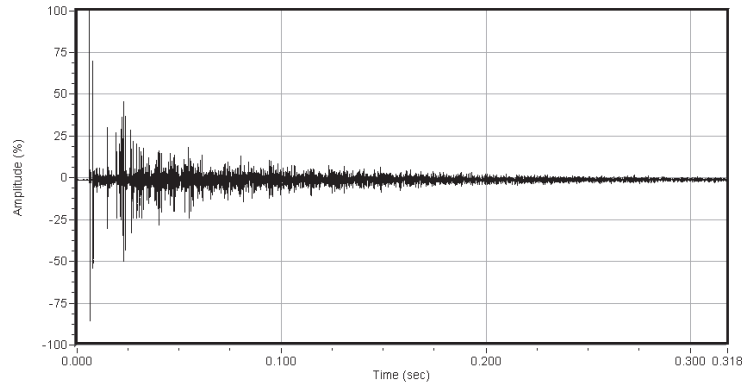


Fig. 7. Room impulse response. Forced by spark-gap generator, wall deviation angle 0° , reverberation time $t_3 = 1.08$ s

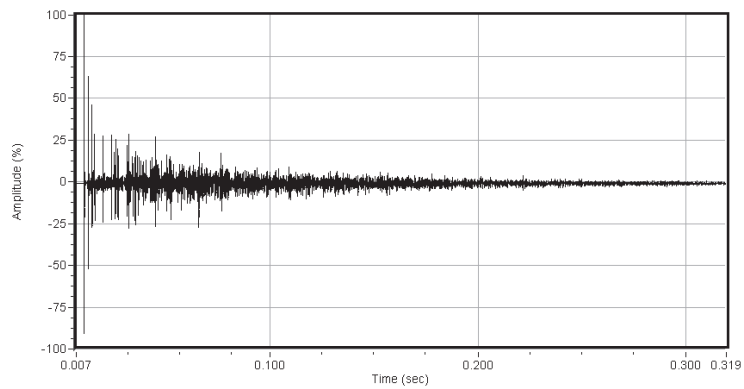


Fig. 8. Room impulse response. Forced by spark-gap generator, wall deviation angle 0° , reverberation time $t_4 = 1.67$ s

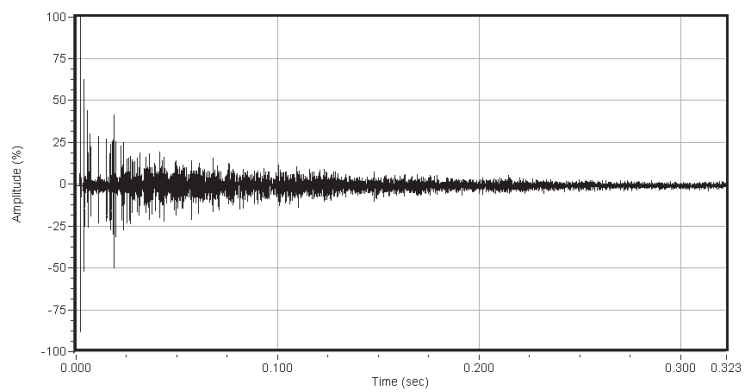


Fig. 9. Room impulse response. Forced by spark-gap generator, wall deviation angle 0° , reverberation time $t_0 = 5.47$ s

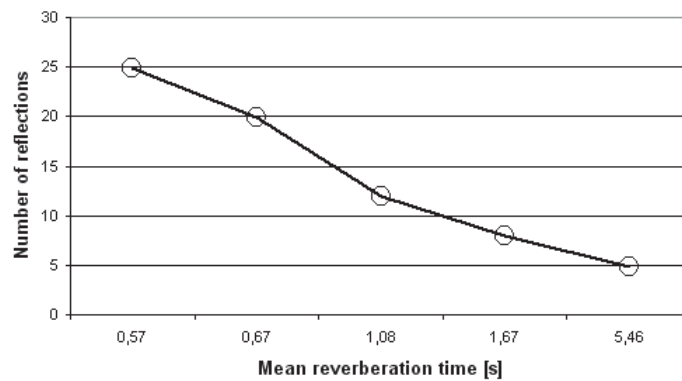


Fig. 10. Dependence of the number of identifiable reflections in the echogram on the chamber's mean reverberation time

4. SOUND ABSORPTION OF FACING PANELS

As facing panels are commonly used in construction and finishing work in interiors, attention should be drawn to their particular noise absorbing properties.

Common acoustic defects of spaces include the occurrence of echo and excessive reverberation for a low frequency range. The experimental work undertaken made it possible to define sound absorption characteristics for given applications, using Fermacell and RIGIPS facing panels.

4.1. Measurement stand

The measurement stand (Fig. 11) consisted of a standard reverberation chamber with a capacity of 186.1 m³, the requisite equipment and samples of the tested material with a surface area of 9.36 m², affixed to the wall on wooden frames. The studies resulted in the reverberation absorption coefficient, determined by the measurement of reverberation time at the absence of pink noise.

5. MEASUREMENT RESULTS

Given below in Figures 12, 13 and 14 are the results of measured and calculated values of the reverberation absorption coefficient for selected acoustic systems built of Fermacell facing panels.

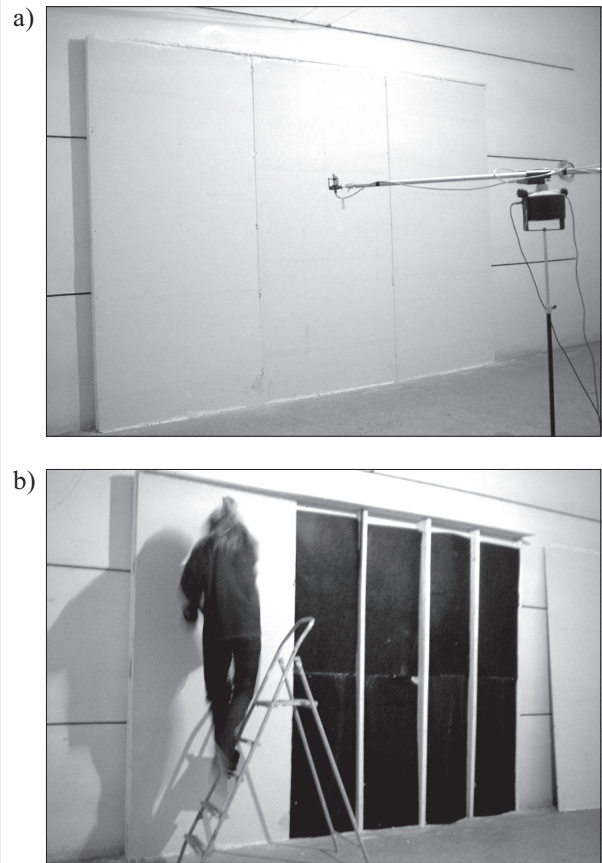


Fig. 11. Measurement stand with the studied acoustic system (a); acoustic system during installation (b)

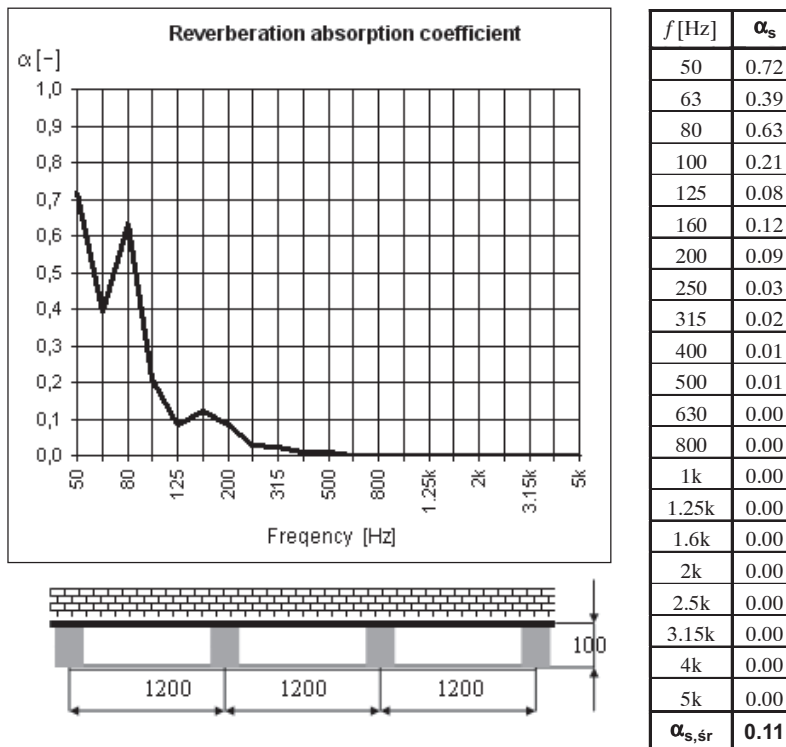


Fig. 12. Sample description surface area: 9.36 m², Fermacell panel on wooden frames, 100 mm voids without filling, silicone-sealed, Manufacturer: XELLA Trockenbau-Systeme GmbH, element dimensions: 2600x1200x12.5 mm, weight per surface area: ~15 kg/m²

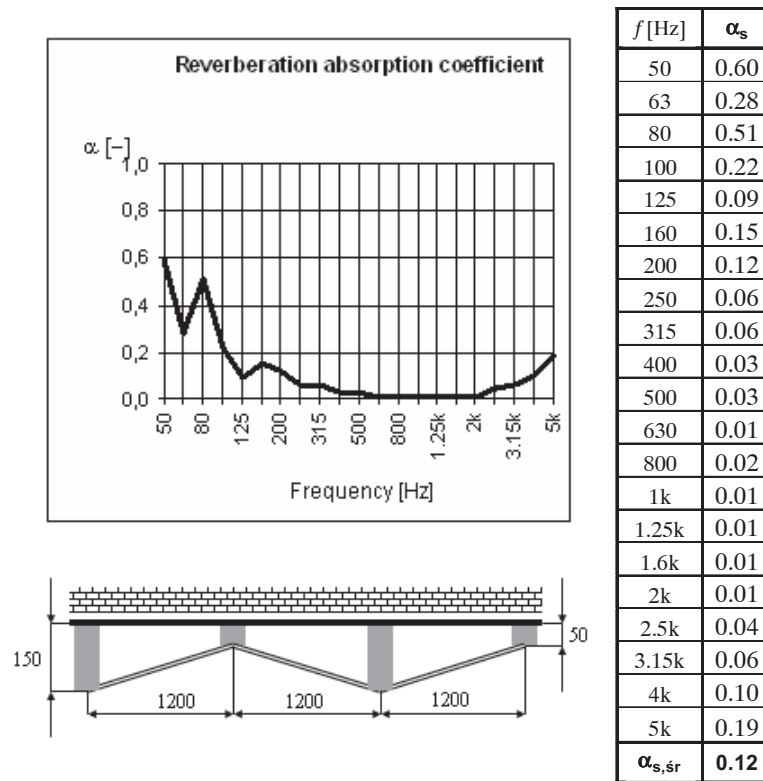


Fig. 13. Sample description: surface area: 9.36 m^2 , Fermacell panel on wooden frames, 50 mm – 150 mm voids without filling, silicone-sealed. Manufacturer: XELLA Trockenbau-Systeme GmbH, element dimensions: $2600 \times 1200 \times 12.5 \text{ mm}$, weight per surface area: $\sim 15 \text{ kg/m}^2$

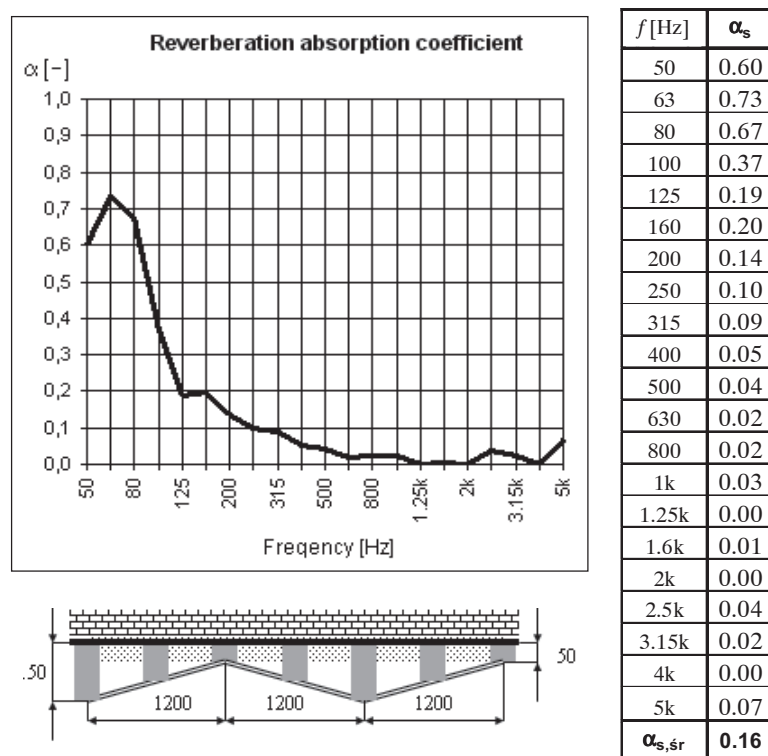


Fig. 14. Sample description: surface area: 9.36 m^2 , Fermacell panel on wooden frames, 50 mm – 150 mm voids filled with 50 mm Ursa mineral wool, silicone-sealed. Manufacturer: XELLA Trockenbau-Systeme GmbH, element dimensions: $2600 \times 1200 \times 12.5 \text{ mm}$, weight per surface area: $\sim 15 \text{ kg/m}^2$

6. PRACTICAL CONCLUSIONS FROM THE EXPERIMENTAL RESULTS

Analysis of the results obtained in laboratory studies made it possible to determine the minimum angle at which the multiple echo occurring between two parallel walls is considerably reduced. The angle is in the range of $5^{\circ} \div 6^{\circ}$. Consequently, a simple and effective method for eliminating this acoustic defect in spaces involves the use of facing panels, e.g., Fermacel panels, which allows for the orientation of opposite planes to be changed by at least 6° .

Experimental studies show that the reverberation time of a space has a significant effect on identification of multiple echo. In spaces with a reverberation time below 1 s, the multiple echo defect will be much more distinct than in spaces with greater reverberation. For instance, by facing the ceiling and floor with sound-absorbing material, and leaving the parallel walls reflexive – the multiple echo effect will be enhanced.

The experiments performed for selected arrangements of panel resonators made it possible to determine the characteristics of reverberation absorption coefficient as a function of frequency. Commonly used facing panels, such as Fermacel panels, show a high value of the sound absorption

coefficient for the frequency range below 200 Hz. It is very easy to design such systems of given acoustic properties for individual applications. The study demonstrated that commonly available gypsum panels, such as fibre-reinforced panels, or panels sandwiched between two paper layers, allow the construction of low-frequency acoustic systems that combining good sound-absorbing and sound-dispersing properties. This type of acoustic enhancement of interiors allows for high acoustic standards of spaces to be attained at limited costs of materials and labour.

References

- [1] Engel Z., Kamisiński T.: *A Pulsed Sound Source Reference Standard*. Polish Technical Review, 11, 1991, 2–3
- [2] Ingard K.U.: *Sound Absorption Technology*. Ver. 94–02
- [3] Kamisiński T., Bankowicz D.: *Okladziny płytowe wewnątrz jako dźwiękochłonne urządzenia akustyczne*. First International Conference Architecture without Limits, Lublin 04–05 November 2004
- [4] Kamisiński T., Czerny R.: *Okladziny płytowe wewnątrz jako urządzenia akustyczne rozpraszające*. First International Conference Architecture without Limits, Lublin 04–05 November 2004
- [5] Malecki I.: *Teoria fal i układów akustycznych*. Warszawa, PWN 1964
- [6] SIA Software Company Inc.: *Acoustic and Analysis Software Acoustic Tools*. Ver. 4