INFLUENCE OF THE CONFIGURATION OF PHONO AND THERMAL-INSULATING GLAZING STRUCTURE OF SOME PVC WINDOW PROFILES ON THE AIRBORNE SOUND INSULATION – CASE STUDY

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ABSTRACT

After conducting laboratory acoustic measurements of airborne sound insulation for several windows with the same type of PVC profiles, equipped with different types of phono- and thermal - insulating glazings, the influence of the window's glazed part (glass) structure configuration on airborne sound insulation was analyzed. The configuration of the structure's glazed part requires its composition of glass sheets with different thicknesses or intermediate layers of air with different thicknesses. This configuration has an important influence on the acoustic response of windows, namely on the index of air noise sound insulation, R_w, and on the behavior of the entire measurement frequency range.

Keywords: acoustics; airborne sound insulation; thermo-phono-insulating glazing; window

REZUMAT

În urma efectuării în laborator a unor măsurări acustice de izolare la zgomot aerian pentru o serie de ferestre având acelaşi tip de profile PVC, echipate cu diferite tipuri de geamuri termo - fono - izolatoare, s-a analizat influența configurației structurii părții vitrate (geamului) a ferestrei asupra izolării acustice la zgomot aerian realizată de aceasta. Configurația structurii părții vitrate presupune alcătuirea acesteia din foi de geam având grosimi egale sau diferite şi din straturi intermediare de aer cu diferite grosimi. Această configurație are o influență importantă asupra răspunsului acustic al ferestrelor, respectiv asupra indicelui de izolare acustică la zgomot aerian, R_w, cât şi asupra comportării pe întreaga gamă de frecvențe de măsurare.

Cuvinte cheie: acustică; izolare acustică la zgomot aerian; geam termofonoizolator; fereastră

1. INTRODUCTION

Many scientific research institutes from European countries carry on activities concerning building acoustics, performing tests on different building elements for finding their acoustics.

First, it is necessary to define a window from the point of view of acoustic characterization; then, the airborne sound insulation defined by the sound reduction index "*R*" and by the airborne sound insulation evaluation index, "R_w" must be provided. Usually, the windows manufacturers need to have this acoustic characterization for their products.

The determination of sound insulation corresponding to a certain construction element is made by acoustical measurements, which determine both the air sound transmission and the structural sound transmission.

Measurements can be performed either in the laboratory, where the degree of reduction of sound transmission through a partition building element before being applied in a building is investigated, or in a completely finished building, where the degree of sound insulation between certain rooms in the building, rooms that are separated by different construction elements (floors, walls, doors etc.) is verified.

By its nature (i.e., by the way of propagation), the noise produced in a building can be:

– airborne noise - which arises and spreads through the air;

- structural noise (produced by the vibration of an object, directly transmitted to a solid part, through which it is propagated), which, can be:
  - impact noise – emitted by a construction element that vibrates due to a direct shock;
  - noise from installations - spread through the building structure.

The acoustic insulation represents the full set of measures taken to reduce noise transmission from the source to the receiver (people or places which should be protected).

The insulation of a room against noise from outside the building depends, on one hand, on the quality of the opaque part of the facade element (the wall), and, on the other hand, on the glazing part of the facade element (the window).

The airborne sound insulation index

Due to the special acoustic conditions in the laboratory, the sound transmission on flanking paths is excluded or considered as having no practical importance.

In buildings, in addition to the direct transmission of sound through the partition elements, there is a major transmission between adjacent rooms through flanking paths, other than the direct path. Thus, either the lateral walls or the ceiling and the floor, adjacent to the analyzed partition element, can be put in vibration, becoming thus, themselves, noise sources. Due to these reasons, for the characterization of the degree of airborne sound insulation of a specific building element, there are defined different indices (e.g. an index for laboratory measurement (R_w) and another index for in situ measurement (R'_w)).

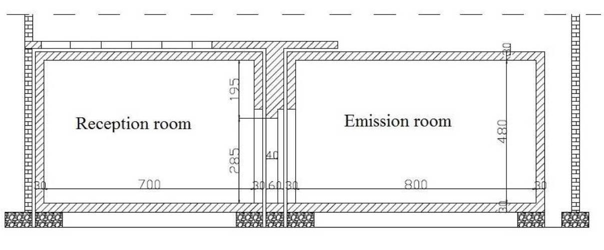


Fig.1 - Longitudinal section through airborne sound insulation test facility, Building Acoustic Laboratory, INCERC Bucharest Branch

Fig. 1

Fig. 1 shows an example of an airborne sound insulation test facility, without flanking transmissions.

Considering that in situ, due to flanking transmission paths, the sound insulation given by a building element is sometimes less than the value obtained in the laboratory, it is necessary, in order to ensure a sound insulation, to use elements which have the airborne sound insulation index higher than the one obtained in the laboratory with 5 to 7 dB.

In the case of laboratory measurements, the acoustic insulation capacity of a partition element located between two adjacent rooms is characterized by the sound reduction index R, defined, according to SR EN ISO 10140-2:2011, by:

$$R = L_1 - L_2 + 10\lg\frac{S}{A} \quad [\text{dB}] \qquad (1)$$

where:

L_1 - room noise level emission [dB]
L_2 - noise level in the receiving room [dB]
S - the area of the measured wall [m^2]
A - the equivalent sound absorption area, in the receiving room [m^{2}UA]

The airborne sound insulation index, R_w, is expressed by a single value, which is obtained by comparing the curve of R with a standardized reference curve.

2. PRESENTATION OF THE MEASUREMENT METHOD

The paper presents a study on the results of several acoustical laboratory measurements of airborne sound insulation for nine window structures with the same type of PVC profiles, equipped with different phono- and thermal-insulating glasses, and the analysis of the influence of the window's glazed part (glass) structure configuration on the airborne sound insulation.

The windows with PVC profiles which were measured are made of two movable wings, one for tilt-turn, with mullion and equipped with phono- and thermal-insulating glasses with different structures.

All measured windows have the same type of frame, overall dimensions L × H = 1500 mm × 1250 mm, 4 hinges and seals for the sealing of the insulating glass and of the frame and sash.

The glazed part (the glass) has the following characteristics: the total thickness of the glass was kept unchanged (24 mm) and only the configuration of the phono- and thermal-insulating glass structure was changed, i.e. there were changed both the thickness of the glass sheets and the thickness of the intermediate air layer.

In the case of acoustical characterization, the airborne sound insulation index, R_w, for a window, depends on glass quality, woodwork quality and joint sealing.

Windows made from a single sheet of glass are often insufficient in terms of thermal insulation and sound insulation. Double glazed glass windows have higher phono- and thermal -insulating characteristics. These can be improved by introducing an inert gas into the space between the glass sheets (thus obtaining a supplement of 2-3 dB to the sound insulation index) or by making each of the glass sheets of two glasses separated by an acrylic resin foil with thickness greater or equal than 1 mm.

In the case of windows from PVC profiles, further analyzed in the article, laboratory measurements to determine their airborne sound insulation were performed at the airborne insulation laboratory test facility, located in Building Acoustics Laboratory of INCD URBAN-INCERC, INCERC Bucharest Branch, in accordance with SR EN ISO 10140-2 "Acoustics. Laboratory measurement of sound insulation of building elements. Part 2: Measurement of airborne sound insulation".

The evaluation of acoustic insulation of the test specimen was done in accordance with SR EN ISO 717-1 "Acoustics. Rating of sound insulation in buildings and of building elements. Part 1: Airborne sound insulation".

Based on the records made in the emission room and in the receiving room of the airborne insulation test facility, the equivalent noise level was measured, in 1/3 octave, for a frequency range between 100 Hz and 5000 Hz. The sound reduction index "R_i" of the test specimen was determined for each position "i" of the loudspeaker and for each central frequency of the one third octave band, according to SR EN ISO 10140-2, using:

$$R_i = L_1 - L_2 + 10 \lg \frac{S}{A} \text{ (dB)} \qquad (1')$$

where:

- L_1 is the average sound pressure level, in the emission room, in dB;
- L_2 is the average sound pressure level, in the receiving room, in dB;
- S is the test specimen area, in m^2, which is equal to the opening test;
- A is the equivalent sound absorption area in the receiving room, in m^2.

The sound reduction index "R" of the test specimen is then calculated as follows:

$$R = -10 \lg \frac{1}{n} \sum_{i=1}^{n} 10^{-R_i/10} \qquad (2)$$

From the results obtained according to SR EN ISO 10140-2 for the sound attenuation index "R", it was performed, by using SR EN ISO 717-1, the calculation of the actual airborne sound insulation evaluation index, "R_w", for the tested windows.

The test result is presented as an airborne sound insulation evaluation index "$R_w(C, C_{tr})$", determined according to SR EN ISO 717-1, where C and C_{tr} are the spectrum adaptation terms, determined according to SR EN ISO 717-1. The measurement results are presented synthetically, in forms containing both main product data and test results, as tables and graphs.

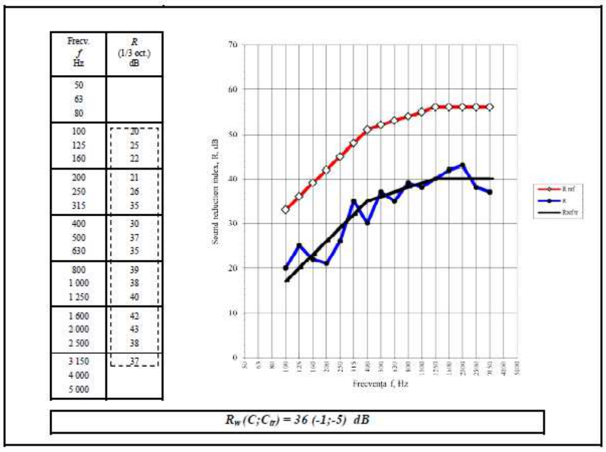
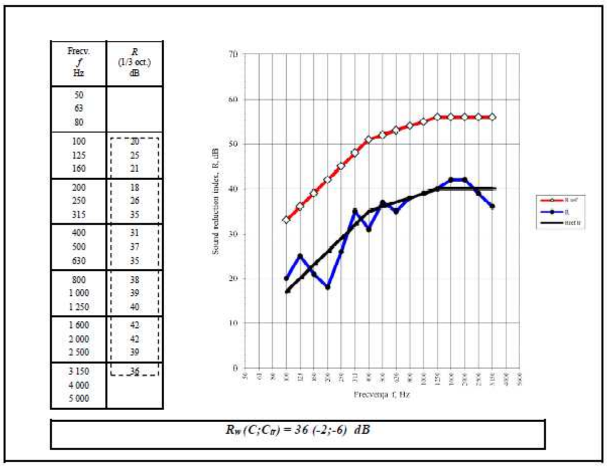
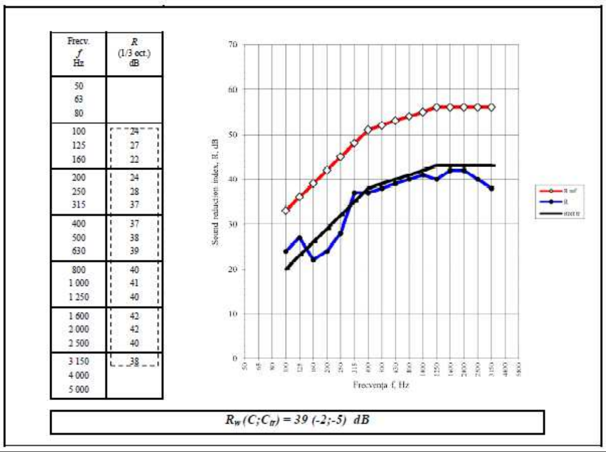
The international standard SR EN ISO 717-1 "Acoustics. Rating of sound insulation in buildings and of building elements. Part 1: Airborne sound insulation" has as its object the standardization of a method by which the real curve of sound reduction indexes, expressed as a function of frequency, can be converted into a single number that characterizes the acoustical performance of a soundproofing material or product (i.e. R_w, in the case of airborne sound).

The expression of evaluation indexes by a single quantity is used to estimate the airborne sound insulation and to simplify the formulation of technical regulations specific to acoustic requirements of different types of buildings. The performance levels of evaluation indexes are given for different types of activities that take place in the rooms of buildings.

3. PRESENTATION OF MEASUREMENTS RESULTS FOR THE CASE STUDY

The acoustical measurement results, performed for the nine analyzed window structures, are presented below in tabular and graphical form (Table 1 and Table 2).

Table 1

Struct. no.	Window description	Graphical representation of results
1	**PVC profiles window**, equipped **with phono- and thermal-insulating glass, with the structure 4-16-4 mm** • glazing: phono and thermal-insulating glass, with structure: 4-16-4 mm - glass sheet: 4 mm thickness - intermediate air layer: 16 mm thickness - glass sheet: 4 mm thickness *Test result:* **R_w (C, C_{tr}) = 36 (-1,-5) dB**	
2	**PVC profiles window**, equipped **with** low-E **phono- and thermal-insulating glass, with the structure 4-16-4 mm** • glazing: Low-E phono- and thermal-insulating glass,with structure:4-16-4mm - glass sheet: 4 mm thickness - intermediate air layer: 16 mm thickness - glass sheet: 4 mm thickness *Test result:* **R_w (C;C_{tr}) = 36 (-2;-6) dB**	
3	**PVC profiles Window**, equipped **with phono and thermal-insulating glass, with the structure 8-12-4 mm** • glazing: phono and thermal-insulating glass, with structure: 8-12-4 mm - glass sheet: 8 mm thickness - intermediate air layer: 12 mm thickness - glass sheet: 4 mm thickness *Test result:* **R_w (C;C_{tr}) = 39 (-2;-5) dB**	

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PVC profiles Window, equipped **with phono and thermal-insulating glass, with the structure** 10-10-4 mm

• glazing: phono and thermal-insulating glass, with structure: 10-10-4 mm
- glass sheet: 10 mm thickness
- intermediate air layer: 10 mm thickness
- glass sheet: 4 mm thickness

Test result:
$R_w(C;C_{tr})$ = 39 (-1;-3) dB

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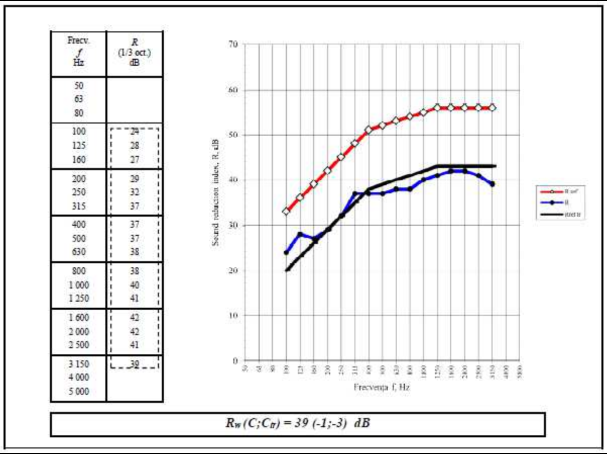

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PVC profiles Window, equipped **with phono and thermal-insulating glass, with the structure** 10-6-8 mm

• glazing: phono and thermal-insulating glass, with structure: 10-6-8 mm
- glass sheet: 10 mm thickness
- intermediate air layer: 6 mm thickness
- glass sheet: 8 mm thickness

Test result:
$R_w(C;C_{tr})$ = 39 (-1;-3) dB

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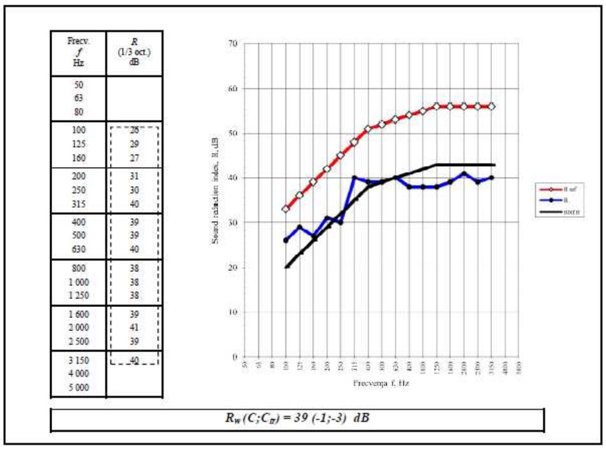

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PVC profiles Window, equipped **with phono and thermal-insulating glass, with the structure** 5-15-4 mm

• glazing: phono and thermal-insulating glass, with structure: 5-15-4 mm
- glass sheet: 5 mm thickness
- intermediate air layer: 15 mm thickness
- glass sheet: 4 mm thickness

Test result:
$R_w(C;C_{tr})$ = 39 (-2;-6) dB

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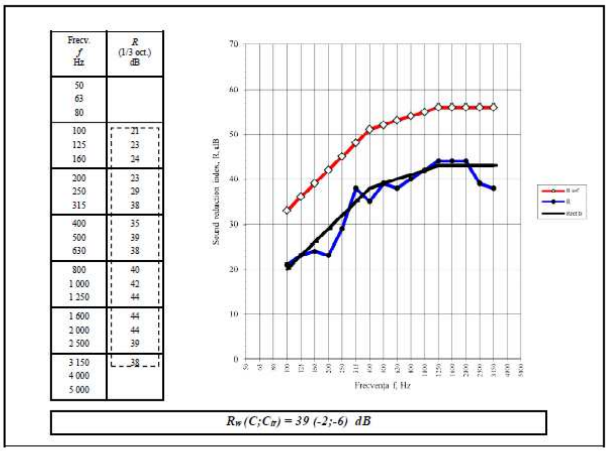

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PVC profiles Window, equipped **with phono and thermal-insulating glass, with the structure** 6-13-5 mm

• glazing: phono and thermal-insulating glass, with structure: 6-13-5 mm
- glass sheet: 6 mm thickness
- intermediate air layer: 13 mm thickness
- glass sheet: 5 mm thickness

Test result:
$R_w(C;C_{tr})$ = 39 (-1;-5) dB

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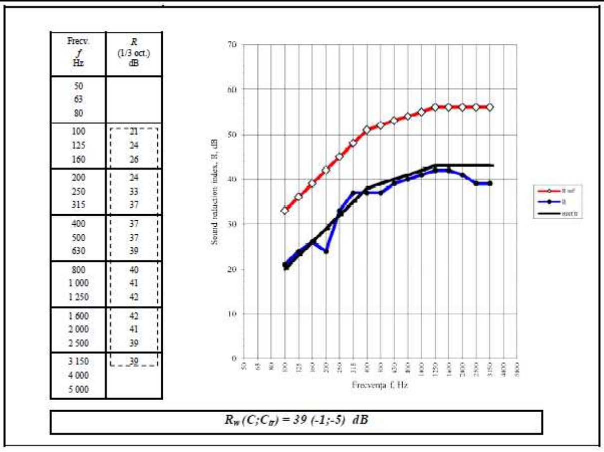

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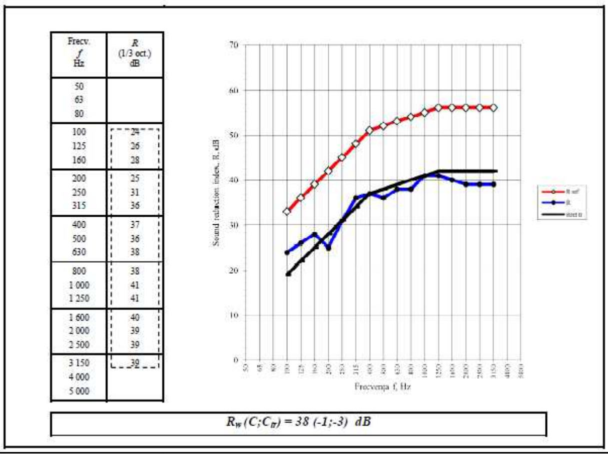
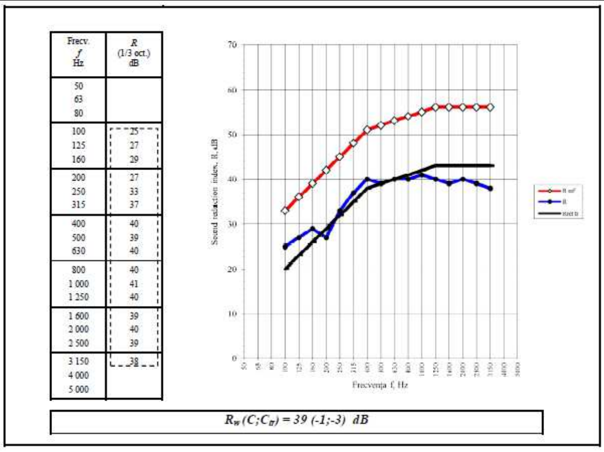
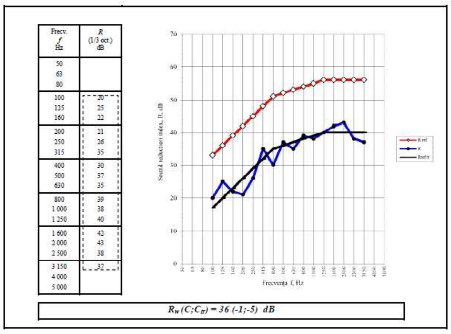
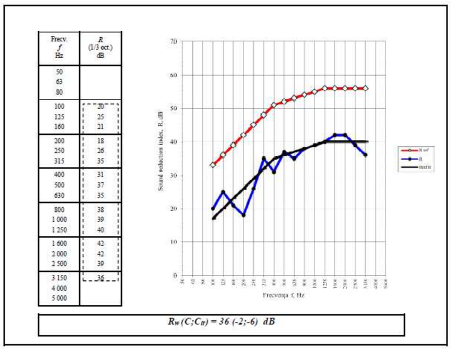
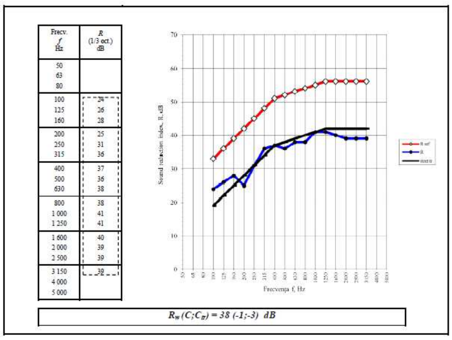
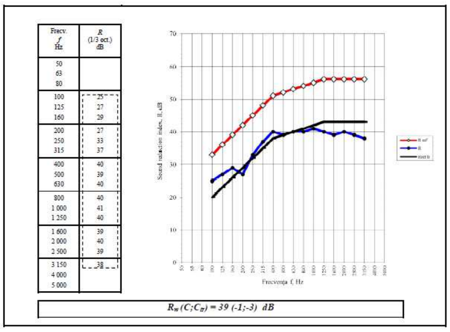
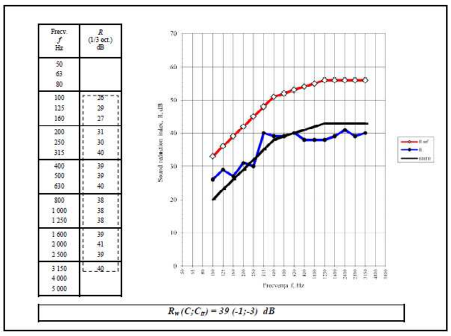
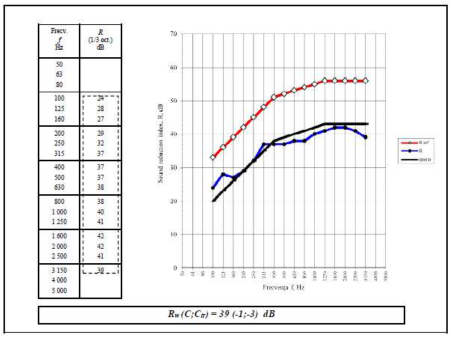
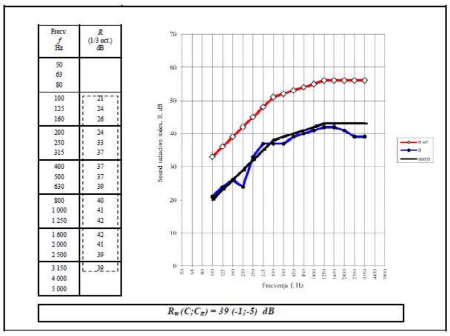
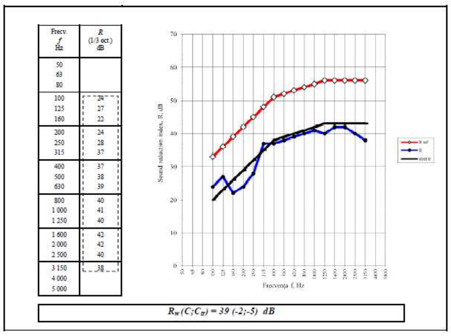
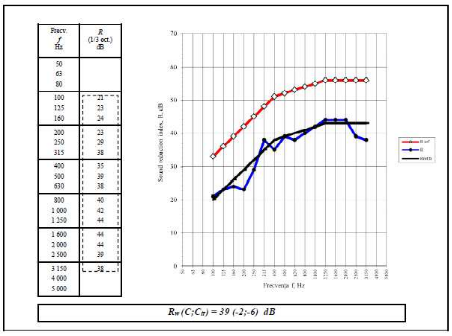
8	**PVC profiles Window**, equipped **with phono and thermal-insulating glass, with the structure** 8-10-6 mm • glazing: phono and thermal-insulating glass, with structure: 8-10-6 mm - glass sheet: 8 mm thickness - intermediate air layer: 10 mm thickness - glass sheet: 6 mm thickness *Test result:* **R_w (C;C_{tr}) = 38 (-1;-3) dB**	
9	**PVC profiles Window**, equipped **with phono and thermal-insulating glass, with the structure** 10-8-6 mm • glazing: phono and thermal-insulating glass, with structure: 10-8-6 mm - glass sheet: 10 mm thickness - intermediate air layer: 8 mm thickness - glass sheet: 6 mm thickness *Test result:* **R_w (C;C_{tr}) = 39 (-1;-3) dB**	

Table 2

Struct. No.	Window type	Airborne sound insulation index	Graphical representation
1	PVC profiles Window, equipped with phono and thermal-insulating glass, with the structure 4-16-4 mm	R_w (C;C_{tr}) = 36 (-1;-5) dB	
2	PVC profiles Window, equipped with low-E thermo- and phono-insulating glass, with the structure 4-16-4 mm	R_w (C;C_{tr}) = 36 (-2;-6) dB	

8	PVC profiles Window, equipped with phono and thermal-insulating glass, with the structure 8-10-6 mm	$R_w\,(C;C_{tr})$ = 38 (-1;-3) dB	
9	PVC profiles Window, equipped with phono and thermal-insulating glass, with the structure 10-8-6 mm	$R_w\,(C;C_{tr})$ = 39 (-1;-3) dB	
5	PVC profiles Window, equipped with phono and thermal-insulating glass, with the structure 10-6-8 mm	$R_w\,(C;C_{tr})$ = 39 (-1;-3) dB	
4	PVC profiles Window, equipped with phono and thermal-insulating glass, with the structure 10-10-4 mm	$R_w\,(C;C_{tr})$ = 39 (-1;-3) dB	
7	PVC profiles Window, equipped with phono and thermal-insulating glass, with the structure 6-13-5 mm	$R_w\,(C;C_{tr})$ = 39 (-1;-5) dB	

3	PVC profiles Window, equipped with phono and thermal-insulating glass, with the structure 8-12-4 mm	$R_w\,(C;C_{tr})$ = 39 (-2;-5) dB	
6	PVC profiles Window, equipped with phono and thermal-insulating glass, with the structure 5-15-4 mm	$R_w\,(C;C_{tr})$ = 39 (-2;-6) dB	

4. RESULTS AND CONCLUSIONS

The analysis was performed by comparing both the results obtained for airborne sound insulation index, R_w, for all the nine types of glazing structures (denoted by structure 1 ... 9, according to the notations in the tables) and the results obtained for structures of glazings, coupled considering the characteristics of the glazing components (thickness of the glass sheets and thickness of the intermediate air layers).

Both the airborne sound insulation index values, R_w, and the response of the acoustical behavior on the frequency range, represented in graphs, were studied comparatively.

The analysis was performed taking into account that there were similar characteristics for all nine types of windows, namely:

- all measured windows have the same type of frame, overall dimensions L x H = 1500 mm x 1250 mm, 4 hinges and seals for the sealing of the insulating glass and of the frame and sash;
- the glazed part (the glass) had the following characteristics: total thickness of the glass was kept unchanged, respectively 24 mm, only the configuration of the phono- and thermal-insulating glass structure was changed, i.e.: it were changed both the thickness of the glass sheets and the thickness of the intermediate air layer.

By analyzing the presented results, the following conclusions could be drawn:

- for the nine types of windows, the airborne sound insulation index, R_w, increases from 36 dB to 39 dB, with the increase of the thickness of the glass sheets used to make the glazing, from 4 mm to 10 mm;
- in the case of two windows, *structures 4 and 3*, with different components of the glazed part, 10-10-4 mm and 8-12-4 mm, but for which it was obtained the same result R_w = 39 dB, it was observed that greater or smaller thickness of the glass sheets positioned towards the noise source (i.e. those of 10 mm and 8 mm were placed to the noise source), affect the values obtained for the spectrum adaptation terms of the airborne sound insulation index, R_w, namely (C, C_{tr}), where C is the spectrum adaptation term calculated with spectrum No. 1 (weighted pink noise) and C_{tr} is the spectrum adaptation term calculated with spectrum No. 2 (weighted urban traffic noise). Both spectrum adaptation terms are determined according to SR EN ISO 717-1.

It appears that both spectrum adaptation terms, C and C_{tr}, have lower values, R_w (C,

C_{tr}) = 39(-1, -3) dB, where the sheet of glass is thicker (10 mm) and greater values R_w (C, C_{tr}) = 39 (-2,-5) dB, where the sheet of glass with lower thickness (8 mm), which shows that it performed better insulation from traffic noise in case of providing glass sheets with greater thicknesses to this type of source.

- in the case of three windows, *structures 9, 5 and 4*, which have different components of the glazed part, i.e. 10-8-6 mm, 10-6-8 mm and 10-10-4 mm, but for which it was obtained the same result R_w = 39 (-1,-3) dB, it was observed that:
  - the air layer with greater thickness, 10 mm, leads to a better behavior of insulation on the frequency range of 1250 Hz ... 3150 Hz,
  - at 315 Hz it shows a jump of insulation, and graphical values of the frequency range 315 Hz ... 800 Hz are approximatively constant, with small differences;
- by comparing structures 9, 5 and 4, which have different components of the glazed part, i.e. 10-8-6 mm, 10-6-8 mm and 10-10-4 mm, with the other structures, is found that the structures with glass sheets having the maximum thickness 10 mm, located near to the noise source, have a better behavior and an increasing insulation, on the frequency range between 100 Hz ... 250 Hz, comparing with the rest of the structures;
- in the case of two windows, structures 1 and 2, which have different components of the glazed part, i.e. 4-16-4 and 4-16-4 mm with Low-E, for which R_w obtained the same result, but with different spectrum adaptation terms, R_w (C, Ctr) = 36 (-1,-5) dB, and R_w (C, Ctr) = 36 (-2,-6) dB, it was observed that Low-E foil influences the values obtained for spectrum adaptation terms of airborne sound insulation index, R_w, namely (C; C_{tr}), leading to a weaker insulation behavior towards the traffic noise, this behavior resulting too from the fact that the graph shows a pronounced insulation decrease at 200 Hz, which is due to the higher air layer of 16 mm and to the smaller, of 4 mm, thickness of the glass sheets;
- by comparing structures 1, 2, 3 and 7, which have different components of the glazed part, i.e. 4-16-4 mm and 4-16-4 mm with Low-E, 8-12-4 mm, 6-13-5 mm, and which are structures with high air layer thickness and smaller thickness of the glass sheets, with the rest of the structures, it results that the graph shows a pronounced drop at 200 Hz, having a low insulation behavior on the frequency range 100 Hz ... 250 Hz, towards to the rest of the structures.
- by comparing all the analyzed structures, it results that, overall, the graph values show a decay (more or less pronounced) at the frequency of 200 Hz and a pronounced jump at the frequency of 315 Hz, which is due to the overall configuration of the glazed part (glass) and, respectively, to the total thickness of 24 mm, for all the structures.

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