Case Report / Technical Paper

ACOUSTICAL PROPERTIES OF SOME MODERN PARTITION GLASS WALLS SYSTEMS – CASE STUDY

Ioana Mihaela ALEXE[1], Marta Cristina ZAHARIA[2]
[1]Dipl. Eng., NRDI URBAN-INCERC, INCERC Bucharest Branch, e-mail: ioanamihelaalexe@yahoo.com
[2]PhD Dipl.Eng., NRDI URBAN-INCERC, INCERC Bucharest Branch, e-mail: marta_cristina_zaharia@yahoo.co.uk

ABSTRACT

The case study presents the results of laboratory measurements carried out for the determination of airborne sound insulation properties for various modern partition glass walls systems.
The analyzed partition glass walls were made with structures of aluminum profiles and with sheets of glazed materials. Laboratory measurements for determining the airborne sound insulation of walls were performed in the airborne sound insulation stand of Building Acoustics Laboratory of NRDI URBAN INCERC, INCERC Bucharest Branch, in accordance with EN ISO 10140- 2 "*Acoustics. Laboratory measurement of sound insulation of building elements. Part 2: Measurement of airborne sound insulation*". Measurement results are presented as airborne sound insulation indexes, R_w, and in graph form in the range of frequency 100 ... 3150 Hz. Rating of sound insulation of the walls was made in accordance with EN ISO 717-1 "*Acoustics. Rating of sound insulation in buildings and of building elements. Part 1: Airborne sound insulation*".
After analyzing the results of the measurements, conclusions were drawn regarding the influence of partition glass walls structure on sound insulation properties, both on airborne sound insulation index, R_w, and on graphical results in the frequency range.

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

REZUMAT

Studiul de caz prezintă rezultatele măsurărilor în laborator efectuate pentru determinarea proprietăților de izolare acustică la zgomot aerian pentru diferite sisteme moderne de pereți de compartimentare din sticlă. Pereții de compartimentare din sticlă analizați au fost realizați cu structuri din profile de aluminiu şi cu fețe din materiale vitrate. Măsurătorile pentru determinarea în laborator a izolării acustice la zgomot aerian a pereților s-au efectuat în standul de determinare a izolării acustice la zgomot aerian al Laboratorului Acustica Construcțiilor din INCD URBAN-INCERC, Sucursala INCERC Bucureşti, în conformitate cu prevederile SR EN ISO 10140-2 "*Acustică. Măsurarea în laborator a izolării acustice a elementelor de construcții. Partea a 2-a: Măsurarea izolării acustice la zgomot aerian*". Rezultatele măsurătorilor sunt prezentate sub formă de indici de izolare acustică la zgomot aerian, R_w, şi sub formă de grafice pe domeniul de frecvențe 100…3150 Hz. Evaluarea izolării acustice a pereților s-a făcut în conformitate cu SR EN ISO 717-1 "*Acustică. Evaluarea izolării acustice a clădirilor şi a elementelor de construcții. Partea 1: Izolarea la zgomot aerian*". În urma analizării rezultatelor obținute prin măsurare, s-au formulat concluzii referitoare la influența structurii sistemelor de pereți de compartimentare din sticlă asupra proprietăților acustice de izolare la zgomot aerian, respectiv atât asupra indicelui de izolare acustică la zgomot aerian, R_w, cât şi a rezultatului grafic pe domeniul de frecvențe.

Cuvinte-cheie: acustică; izolare acustică la zgomot aerian; geam termofonoizolator; profile aluminiu

1. INTRODUCTION

Partition glass walls systems are modern systems which have many advantages, such as the following: they are removable, their assembly / disassembly is quick and simple, they provide good sound insulation between partitioned spaces and they have an esthetic design.

Partition walls covered by this case study are manufactured by Mausmann Consulting Ltd. Company. The system is based on the combination of standardized elements with steel structure for supporting and fixing. On these, on each side, decorative printed glass panels of different thicknesses and structures are mounted. The systems are designed for self-supporting partition walls that are mounted inside civil and industrial constructions.

The case study presents the results of laboratory measurements carried out for determining airborne sound insulation properties for various partition glass walls systems of types: VITRUM, DUO, DIVIDO, MODULO and SKY.

2. DESCRIPTION OF THE ANALYZED SYSTEMS AND OF THE USED MATERIALS

The analyzed partition glass walls are made of metal profiles and glazed uppers.

The supporting structure consists of main frame structure composed of steel profiles processed by plastic deformation, bending, rolling and welding. The steel profiles are galvanized.

Metal profiles fitted to the bottom and to the top side are fixed to the floor and the ceiling of the room. These profiles are provided at the bottom (laying) side with two seals of flexible rubber or with adhesive foam tape, that ensures both sealing partition walls and taking any unevenness of the support layer.

The vertical mullion profiles are made of steel, with a geometry which provides a very good resistance to deformation. Mullion profiles are mounted vertically between the upper and lower channel profiles.

The beam profiles are made of steel profiles, also processed by plastic deformation, bending, rolling and welding. They are fixed horizontally between the mullions.

Decorative glass panels are attached to the main frame system with hooks made of galvanized steel or self-drilling screws, depending on the type of panels. The main frame structure is completed with closing profiles, angle attachment profiles, fittings for partition walls, adjustable or fixed, mounting parts etc, made of galvanized steel. The decorative panels are supplied in several types of glass or of modular elements made of aluminum profiles that form frames in which various types of glass panels are mounted.

Partition glass walls systems – VITRUM type

Fig. 1. Detail of the positioning of the VITRUM type (10 safety glass-73-10 safety glass) partition wall system in the airborne sound insulation stand

Fig. 2. Detail of the positioning of the VITRUM type partition wall system (5.1.5 - 73 - 5.1.5) in the airborne sound insulation stand

VITRUM system is a partition wall system made of two safety glass sides, each of

10 mm-thick, and a 10 mm-thick duplex glass (with the structure 5.1.5 mm), arranged in parallel, at a distance of 73 mm from each other. Each vertical side of the wall consists of glass panels placed one in the extension of the other. The joining of glass panels located in the current field was done with double-sided silicon tape, 1 mm-thick. The VITRUM system is built without vertical mullions.

Partition glass walls systems – DUO type

Fig. 3. Detail of the positioning of the partition wall system DUO glass type (6-87-6) in the airborne sound insulation stand

Fig. 4. Detail of the positioning of the partition wall system DUO glass type (6-85-8) in the airborne sound insulation stand

The DUO glass (6-87-6) system is a partition wall system made of two safety glass sides, 6 mm-thick each, arranged in parallel, at a distance of 87 mm from each other. The DUO glass (6-87-6) system is made of two safety glass sides of 6 mm, respectively 8 mm-thick, arranged in parallel, at a distance of 85 mm from each other. The side of safety glass with a thickness of 8 mm was mounted toward the emission room, and the one with the thickness of 6 mm, toward the receiving room.

The sample was built up of three frames made of aluminum profiles. The safety glass sheets were glued on profiles that form the frames, using the Sika system.

Fig. 5. Detail of the positioning of the partition wall system DUO twinglass type (3.1.3-81-6) in the airborne sound insulation stand

Fig. 6. Detail of the positioning of the partition wall system DUO twinglass type (4-83-6), in the airborne sound insulation stand

The DUO twinglass (3.1.3-81-6) system is a partition wall system made of two safety glass sides, that toward the emission room being made of 6 mm-thick safety glass, and that toward the reception room being made of 6 mm-thick duplex glass (with the structure 3.1.3 mm), the sides being arranged in parallel, at a distance of 81 mm from each other. The sample was built of three frames made of aluminum profiles. The safety glass sheets were fixed in frames and the frames were fixed in the system using fastening screws.

The DUO twinglass (4-83-6) system is a partition wall system made of two safety glass sides of 4 mm-, respectively 6 mm-thick, arranged in parallel, at a distance of 83 mm from each other. The sample was built up of three frames made of aluminum profiles. The safety glass sheets were glued on the profiles that form the frames, using the Sika system. The side of safety glass with a thickness of 6 mm was mounted toward the emission room, and that with the thickness of 4 mm, toward the receiving room. In the gap between the vertical steel profiles which form the mullions, polyurethanic foam was inserted.

Partition glass walls systems – DIVIDO type

Fig. 7. Detail of the positioning of the partition wall system DIVIDO twinglass type (4-83-6), in the airborne sound insulation stand

The DIVIDO twinglass (4-83-6) system is a partition wall system made of two safety glass sides, 4 mm- and 6 mm-thick, respectively, arranged in parallel, at a distance of 83 mm from each other. The sample was built up of three frames made of aluminum profiles. The safety glass sheets were fixed in frames, frames being attached to the system using hooks. The side of the safety glass with a thickness of 6 mm was mounted toward the emission room, and that with the thickness of 4 mm, toward the receiving room. In the gap between the vertical steel profiles which form the mullions, polyurethanic foam was inserted.

Fig. 8. Detail of the positioning of the partition wall system DIVIDO twinglass type (6-81-3.1.3), in the airborne sound insulation stand

The DIVIDO twinglass (6-81-3.1.3) system is a partition wall system made of two glass sides, that toward the emission room being made of 6 mm-thick duplex glass (with the structure 3.1.3 mm), and that toward the reception room being made of 6 mm-thick safety glass, the sides being arranged in parallel, at a distance of 81 mm from each other. The sample was built up of three frames on each side, made of aluminum profiles. Safety glass sheets were fixed in frames, frames being attached to the system using hooks.

Partition glass walls systems – MODULO type

Fig. 9. Detail of the positioning of the partition wall system MODULO type (6-86-6), in the airborne sound insulation stand

Fig. 10. Detail of the positioning of the partition wall system MODULO type (4-88-6), in the airborne sound insulation stand

The MODULO (6-86-6) system is a partition wall system made of two safety glass sides of 6 mm thickness each, arranged in parallel, at a distance of 86 mm from each other.

The MODULO (4-88-6) system is a partition wall system made of two safety glass sides of 4 mm, respectively 6 mm thickness, arranged in parallel, at a distance of 88 mm from each other.

Partition glass walls systems – SKY type

Fig. 11. Detail of the positioning of the partition wall system SKY type (with 10 mm thick safety glass), in the airborne sound insulation stand

The side of safety glass with a thickness of 6 mm was mounted toward the emission room, and the one with thickness of 4 mm toward the receiving room.

Fig. 12. Detail of the positioning of the partition wall system SKY type (with duplex glass 5.a2.5), in the airborne sound insulation stand

Each vertical side of the wall is made up of three safety glass panels, the joint being accomplished using mullions made of aluminum profiles.

The SKY system (with 10 mm thickness safety glass) is a partition wall system made of a single safety glass sheet of 10 mm thickness.

The SKY system (with 10 mm thickness duplex glass, with the structure 5.a2.5 mm) is a partition wall system made of a single duplex glass sheet of 10 mm thickness.

The wall consists of glass panels placed one in the extension of the other.

The joining of glass panels located in the current field has been done with double-sided silicon tape with a thickness of 1 mm. The SKY system is built without vertical mullions.

3. DEFINITIONS AND DESCRIPTION OF THE USED TEST METHOD

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

Measurements can be performed either in laboratory, when it is investigated the degree of reduction of sound transmission through a

partition building element before being applied in a building, or in a completely finished building, when the degree of sound insulation between certain rooms in the building is verified, the rooms being separated by different construction elements (floors, walls, doors etc.).

Index of airborne sound insulation

Due to the special acoustic conditions existing in a laboratory, the sound transmission on flanking paths is excluded or without practical importance.

In buildings, in addition to the direct transmission of sound through the partition element, there is a major transmission between adjacent rooms through flanking paths, other than the direct path. Thus, the lateral walls or the ceiling and floor, adjacent to the analyzed partition element, can be put in vibration, themselves becoming noise sources. For these reasons, for characterization of the degree of airborne sound insulation, corresponding to 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)).

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

MEASURING METHOD

The laboratory measurements aimed to determine the airborne sound insulation were performed in the airborne insulation laboratory test facility, located in the Building Acoustics Laboratory of NRDI 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*".

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

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.

C and C_{tr} are the spectrum adaptation terms, determined according to SR EN ISO 717-1.

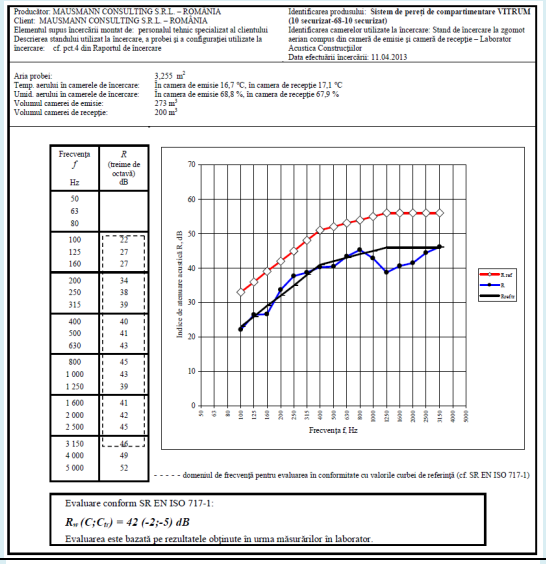
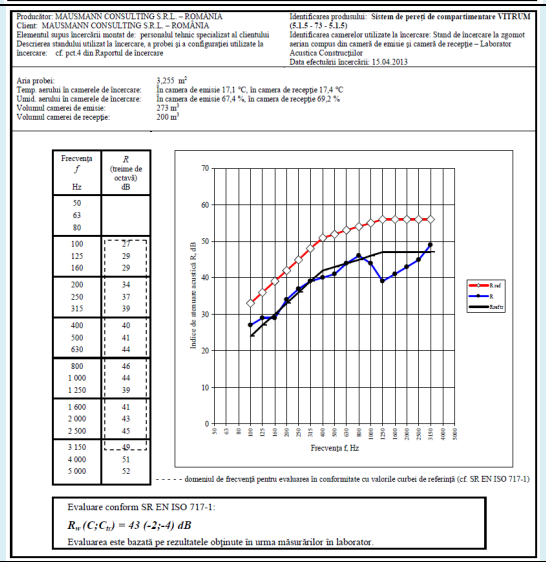
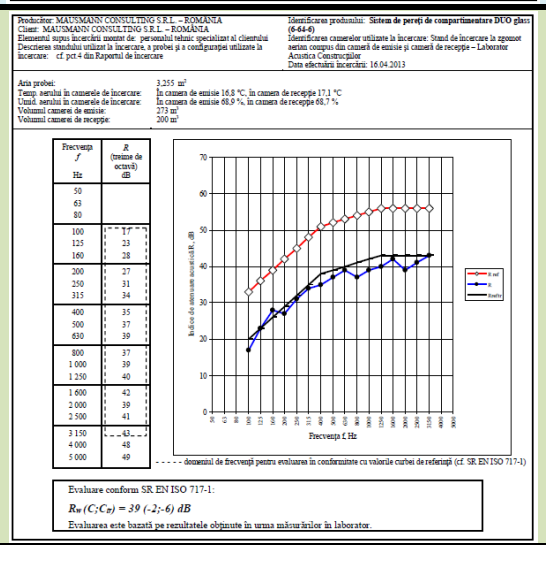
Measurement results are presented synthetically, in forms containing both main product data and test results, in form of table and as a graph.

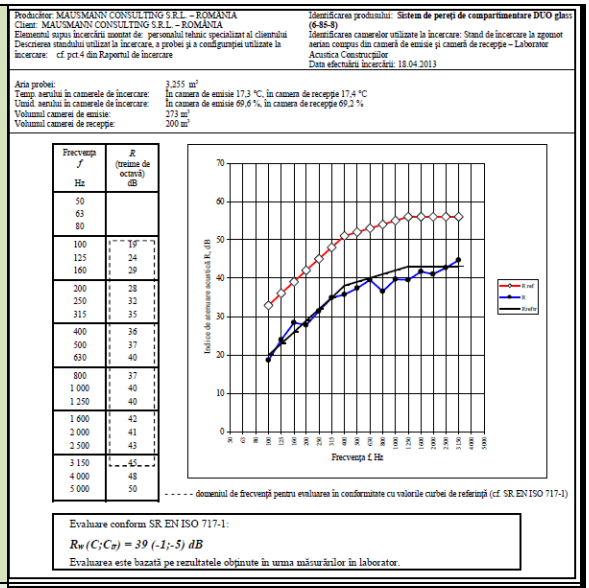
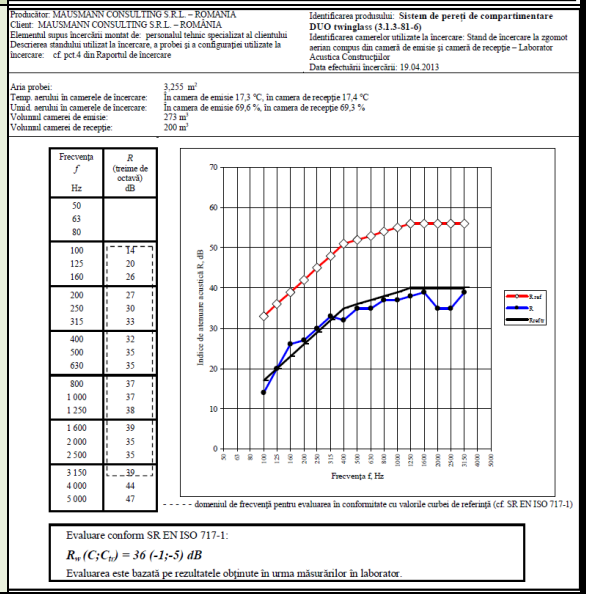
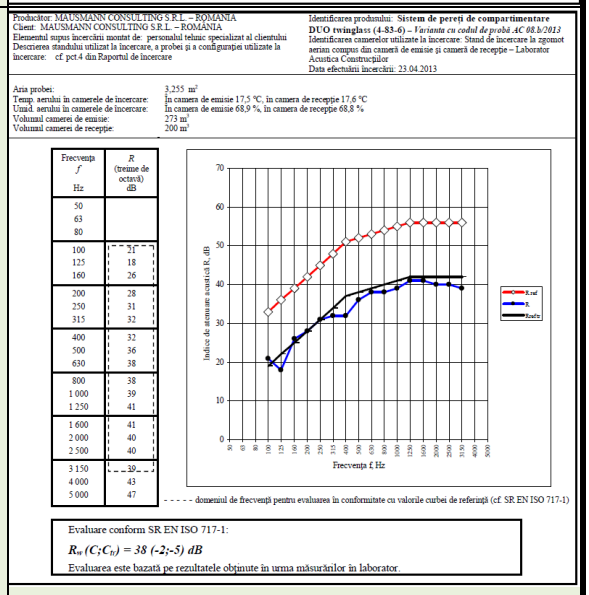
The international standard SR EN ISO 717-1 "*Acoustics. Rating of sound insulation in buildings and of building elements. Part 1: Airborne sound insulation*" has as purpose the standardization of a method by which the real curve of sound reduction indexes as a function of frequency, can be converted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

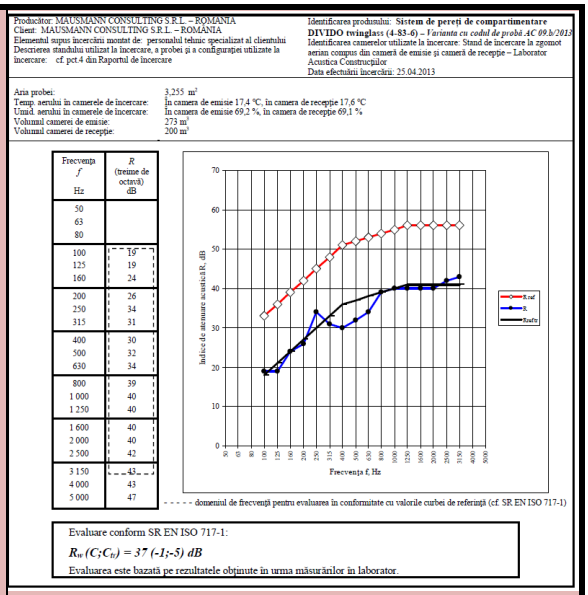
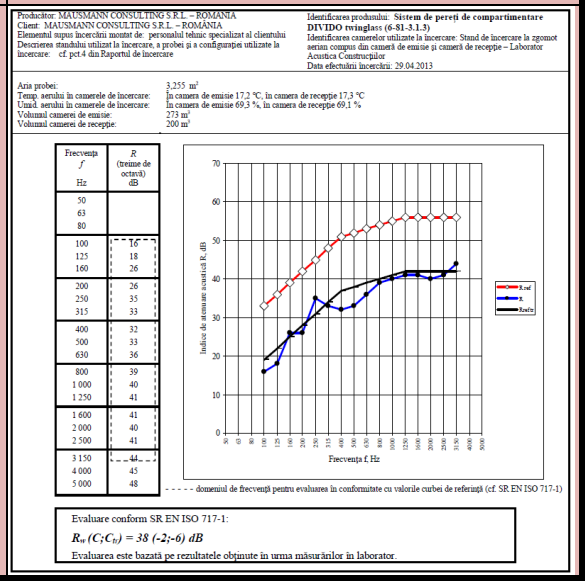
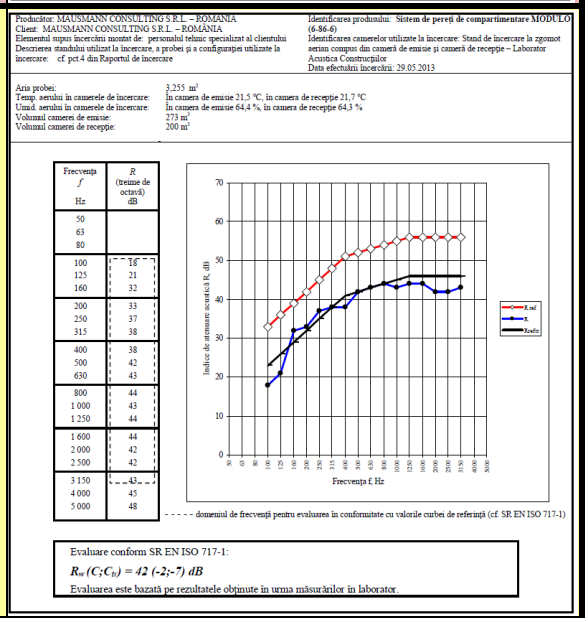
The expression of evaluation indexes by a single quantity is used to estimate the airborne sound insulation and to simplify the formulation of technical regulations specific to acoustic requirements of different types of buildings. The performance levels of evaluation indexes are given for different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

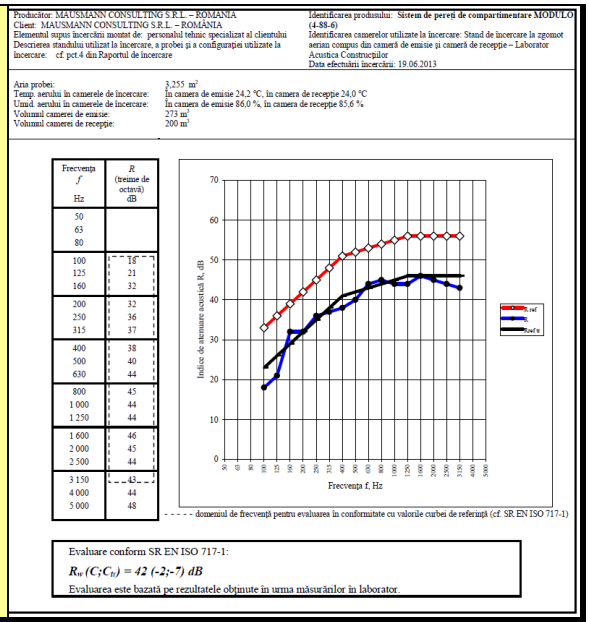
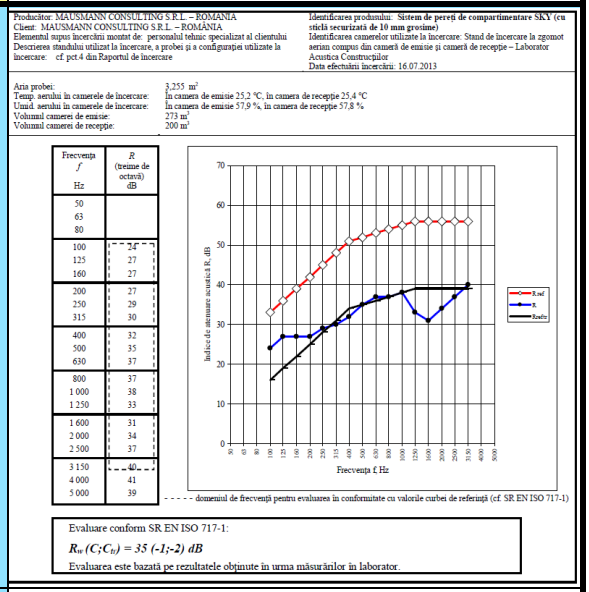
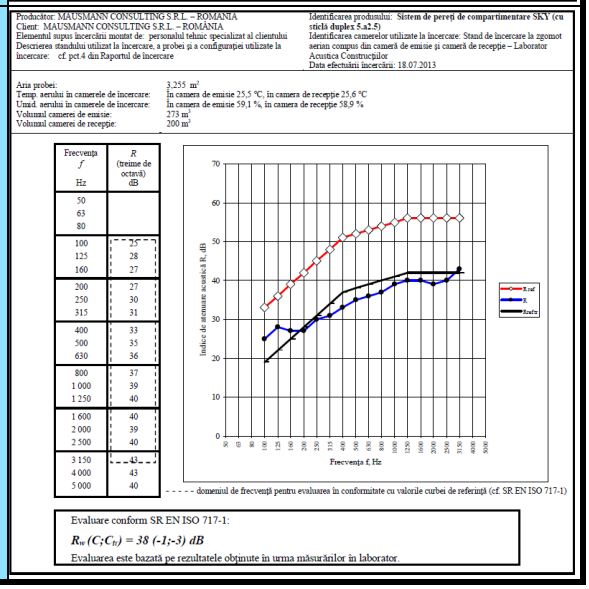
4. PRESENTATION OF MEASUREMENTS RESULTS

Table 1 shows, in graphical and tabular form, the acoustical measurement results, performed for the 12 analyzed partition glass wall systems.

No.	Type of partition glass walls systems	Description of glazing structure	Obtained result, $R_w(C,C_{tr})$	Graphical representation of results
1	**VITRUM (10-73-10)**	• Glazing: - safety glass side of 10 mm thickness - intermediate layer of air of 73 mm thickness - safety glass side of 10 mm thickness Note: Joining of glass panels located in the current field has been done with double-sided silicon tape with a thickness of 1 mm. VITRUM system is built without vertical mullions.	**R_w (C;C_{tr}) = 42 (-2;-5) dB**	
2	**VITRUM (5.1.5-73-5.1.5)**	• Glazing: - duplex glass of 10 mm thickness (with the structure 5.1.5 mm) - intermediate layer of air of 73 mm thickness - duplex glass of 10 mm thickness (with the structure 5.1.5 mm) Note: Joining of glass panels located in the current field has been done with double-sided silicon tape with a thickness of 1 mm. VITRUM system is built without vertical mullions.	**R_w (C;C_{tr}) = 43 (-2;-4) dB**	
3	**DUO glass (6-87-6)**	• Glazing: - safety glass side of 6 mm thickness - intermediate layer of air of 87 mm thickness - safety glass side of 6 mm thickness Note: The sample was built up of three frames made of aluminum profiles. Safety glass sheets were glued on profiles that form the frames using the Sika system.	**R_w (C;C_{tr}) = 39 (-2;-6) dB**	

4	**DUO glass (6-85-8)**	• Glazing: - safety glass side of 6 mm thickness (mounted toward the reception room) - intermediate layer of air of 85 mm thickness - safety glass side of 8 mm thickness (mounted toward the emission room) Note: The sample was built up of three frames made of aluminum profiles. Safety glass sheets were glued on profiles that form the frames using the Sika system.	**R_w (C;C_{tr}) = 39 (-1;-5) dB**	
5	**DUO twinglass (3.1.3-81-6)**	• Glazing: - safety glass side of 6 mm thickness (mounted toward the reception room) - intermediate layer of air of 81 mm thickness - duplex glass side of 6 mm thickness, with the structure 3.1.3 mm (mounted toward the emission room) Note: The sample was built from three frames made of aluminum profiles. The safety glass sheets were fixed in frames and the frames were fixed in the system using fastening screws.	**R_w (C;C_{tr}) = 36 (-1;-5) dB**	
6	**DUO twinglass (4-83-6)**	• Glazing: - safety glass side of 4 mm thickness (mounted toward the reception room) - intermediate layer of air of 83 mm thickness - safety glass side of 6 mm thickness (mounted toward the emission room) Note: The sample was built up of three frames made of aluminum profiles. Safety glass sheets were glued on the profiles that form the frames using the Sika system. In the gap between the vertical steel profiles which form the mullions was inserted polyurethanic foam.	**R_w (C;C_{tr}) = 38 (-2;-5) dB**	

7	**DIVIDO twinglass (4-83-6)**	• Glazing: - safety glass side of 4 mm thickness (mounted toward the reception room) - intermediate layer of air of 83 mm thickness - safety glass side of 6 mm thickness (mounted toward the emission room) Note: The sample was built up of three frames on each side, made of aluminum profiles. Safety glass sheets were fixed in frames, frames being attached to the system using hooks. In the gap between the vertical steel profiles which form the mullions was inserted polyurethanic foam.	**R_w (C;C_{tr}) = 37 (-1;-5) dB**	
8	**DIVIDO twinglass (6-81-3.1.3)**	• Glazing: - safety glass side of 6 mm thickness (mounted toward the reception room) - intermediate layer of air of 81 mm thickness - duplex glass side of 6 mm thickness, with the structure 3.1.3 (mounted toward the emission room) Note: The sample was built up of three frames on each side, made of aluminum profiles. Safety glass sheets were fixed in frames, frames being attached to the system using hooks.	**R_w (C;C_{tr}) = 38 (-2;-6) dB**	
9	**MODULO (6-86-6)**	• Glazing: - safety glass side of 6 mm thickness - intermediate layer of air of 86 mm thickness - safety glass side of 6 mm thickness Note: Each vertical side of the wall is made up of three safety glass panels, the joint being accomplished using mullions made of aluminum profiles.	**R_w (C;C_{tr}) = 42 (-2;-7) dB**	

10	**MODULO (4-88-6)**	• Glazing: - safety glass side of 4 mm thickness (mounted toward the reception room) - - intermediate layer of air of 88 mm thickness - safety glass side of 6 mm thickness (mounted toward the emission room) Note: Each vertical side of the wall is made up of three safety glass panels, the joint being accomplished using mullions made of aluminum profiles.	R_w (C;C_{tr}) = 42 (-2;-7) dB	
11	**SKY (10)**	• Glazing: - a single safety glass sheet of 10 mm thickness. Note: The wall consists of glass panels placed one in the extension of the other. Joining of glass panels located in the current field has been done with double-sided silicon tape with a thickness of 1 mm. SKY system is built without vertical mullions.	R_w (C;C_{tr}) = 35 (-1;-2) dB	
12	**SKY (5.a2.5)**	• Glazing: - a single duplex glass sheet of 10 mm thickness, with the structure 5.a2.5 mm Note: The wall consists of glass panels placed one in the extension of the other. Joining of glass panels located in the current field has been done with double-sided silicon tape with a thickness of 1 mm. SKY system is built without vertical mullions.	R_w (C;C_{tr}) = 38 (-1;-3) dB	

5. ANALYSIS OF RESULTS AND CONCLUSIONS

The analysis was performed by comparing both results obtained for airborne sound insulation index, R_w, for all twelve (12) types of glazed partition walls samples (denoted with 1…12, according to the notation in the tables), specific for the 5 types of analyzed partition systems, and the results obtained for the samples of glazed partition walls. These were coupled taking into account the characteristics of the glazing components (thickness of the glass sheets and of the air layers).

Airborne sound insulation index values, R_w, were studied comparatively and the response of the acoustic behavior in the frequency range was represented in graphs.

The analysis was performed taking into account that there were similar characteristics specific to the 5 types of partition systems analyzed, namely:

- the systems in which the glass sheets mounting was made inside the bordering metal frame, the total thickness of the glazing was kept unchanged, regardless of different thicknesses - from sample to sample - of the glass sheets;
- in case of systems where the glass sheets mounting was made outside the bordering metal frame, the total thickness of the glazing was changed, keeping unchanged the inner distance between the glasses, regardless of different thicknesses - from sample to sample - of the glass sheets;
- all measured samples had the same surface, with the vertical dimensions L x l = 2100 mm x 1550 mm.

By analyzing the above results, the following conclusions were drawn:

- for the ten (10) types of glazing partition wall samples which have vertical glazing consisting of two rows of parallel glass sheets placed at a certain distance, the airborne sound insulation index, R_w, increases from 36 dB to 43 dB, depending on the type of system and its configuration;
- for the 2 (two) types of glazing partition walls samples which have the glazing consisting of only one sheet of glass vertically arranged, the airborne sound insulation index, R_w, increases from 35 dB to 38 dB, depending on the thickness and configuration of the glass sheet structure;
- at the same thickness of 10 mm, a duplex glass insulates to the airborne sound transmission better than a single glass, this is observed in both samples of VITRUM system and of SKY system;
- on the other hand, at the same total thickness of the glazing samples, for example 93 mm in the case of DIVIDO system, even if the interior air layer is 2 mm less (81 mm unto 83 mm) from one sample to another, where one of the sheets is made of duplex glass, leads the result to an improved sound insulation of the sample (eg. 38 dB for sample with duplex glass sheets, compared to 37 dB for the sample with simple glass sheets).
- generally speaking it is confirmed that at the same thickness, duplex glass insulates better than simple glass, explanation being that in the case of simple glass it is created a resonance phenomenon, visible on the chart in the area of medium to / and high frequencies (e.g. in case of 10 mm thickness glass, the frequency range between 1000 ... 3150 Hz, with the most significant decay at the frequency of 1600 Hz); duplex glass does not show this phenomenon, thus leading to an improved sound insulation by increasing the level of the shifted standard curve in the frequency chart, curve depending on which results the value of the airborne sound insulation index, R_w;
- the best system, in terms of acoustical obtained results is the VITRUM system, because it is composed of glass sheets with the greatest thickness: 10 mm and/or 5.1.5 mm;

- at the same total thickness of glazing - e.g. to 98 mm for MODULO system (6-86-6 and 4-88-6) have the same R_w (C; C_{tr}) = 42 (-2; -7) dB, and at 99 mm for DUO glass system, the sample (6-87-6) has R_w (C; C_{tr}) = 39 (-2; -6) dB and the sample (4-88-6) has R_w (C; C_{tr}) = 39 (-1; -5) dB, - the final result, R_w, is the same, a slight difference being observed at the values of corrections, the glass sheet with larger thickness located toward the emission room leading to smaller values for corrections;
- in the case of the 93 mm total thickness of the glazing, for DUO twinglass system, the sample (3.1.3-81-6) has R_w (C; C_{tr}) = 36 (-1, -5) dB and the sample (4-83-6) has R_w (C; C_{tr}) = 38 (-2, -6) dB, it is found that the sample containing the thinner glass sheet of 4 mm has better result, because in the free space between outer frames of the vertical metal profiles of the sample mullions, was placed a strip of dense polyurethane foam.
- the acoustic insulation achieved by SKY system samples is very good, the sample with safety glass sheet (10 mm) has R_w (C; C_{tr}) = 35 (-1, -2) dB and the sample with duplex glass sheet (5.1.5 mm) has R_w(C; C_{tr}) = 38 (-1, -3) dB, thus this type of system is more economically convenient for a beneficiary, as compared to the systems with similar or close acoustical results, having the glazing structure formed by two parallel sheets of glass.

REFERENCES

1. Test reports of the determination of the airborne sound insulation, issued by Building Acoustics Laboratory of INCD URBAN-INCERC, INCERC Bucharest Branch: Test Report No. 3 / 15.04.2013, Test Report No. 4 / 19.04.2013, Test Report No. 5 / 22.04.2013, Test Report No. 6 / 25.04.2013, Test Report No. 7 / 26.04.2013, Test Report No. 11 / 17.05.2013, Test Report No. 12 / 20.05.2013, Test Report No. 13 / 22.05.2013, Test Report No. 14 / 30.05.2013, Test Report No. 15 / 21.06.2013, Test Report No. 18 / 19.07.2013, Test Report No. 19 / 22.07.2013.
2. SR EN ISO 10140-2 *Acoustics. Laboratory measurement of sound insulation of building elements. Part 2: Measurement of airborne sound insulation*.
3. SR EN ISO 717-1 *Acoustics - Rating of sound insulation in buildings and of building elements - Part 1: Airborne sound insulation*.
4. Ioana Mihaela ALEXE, Marta Cristina ZAHARIA, *"The influence of the phono and thermal-insulating glazing structure configu-ration of some PVC profiles windows on the airborne sound insulation – Case study*". Constructii, No. 2/2012 (ISSN: 1221 – 2709).