COMPARATIVE ANALYSIS ON THE PERFORMANCE PROPERTIES OF DIFFERENT TYPES OF PVC WINDOWS

Petranka Naydenova[1], Petar Velev[2], Stanislava Kovacheva[3]
[1]University of Chemical Technology and Metallurgy, Sofia,
e-mail: petranka_naydenova@abv.bg
[2]University of Chemical Technology and Metallurgy, Sofia,
e-mail: pvelev@abv.bg
[3]University of Forestry, Sofia,
e-mail: st_kovacheva@abv.bg

ABSTRACT

The behaviour of wooden, aluminium and various types of PVC joinery has been studied in extreme conditions with a testing device. The resistance of different types of joinery has been determined in occurrence of wind, air and water influence. The sound insulation and heat transfer properties of the double glazing windows made of different materials or a different design have been compared. Based on the studies conducted, the systems with the most stable performance have been established.

Key words: wooden joinery, PVC profiles for doors and windows, performance properties.

INTRODUCTION

The variety in form, size and material for window manufacturing provides a wide range of options and solutions for energy efficiency.

The polyvinylchloride is one of the most important and widely used thermoplastics because of its numerous valuable features, including good processing, chemical resistance and low inflammability. It is widely used in outdoor construction, in production of blinds, windows, outdoor cladding, advertisement signs and other applications, where corrosion and impact resistance, colour, air impermeability and water resistance are of great importance [Anton–Prinet 1999, Grull 2005].

A window made of non-plasticized polyvinylchloride profiles does not require much maintenance and does not need any painting. It is necessary to grease the hardware and rubber sealing from time to time. The market offers PVC windows and doors in a wide range of styles, forms, size and price. The shortcoming of the PVC profiles is the bad weather resistance – after a long period of operation the colour changes.

Wooden windows have a serious advantage as the material used is natural and renewable. They provide very good heat- and acoustic insulation and minimum condensation, as the temperature difference does not affect the wood. The bad processing of timber, however, may cause moist absorption and consequently serious changes in the operational parameters of the manufactured product. The wooden windows with aluminium caps retain minimum quantity of moist, and almost no water condensation is observed [Wegener 2010, Gonzales 2011].

Aluminium windows are resistant to weather impact. They are preferred in regions with mild and humid climate. The aluminium windows with interrupted thermal bridge provide significant thermal resistance.

The window production is evolving all the time: new technologies for profile production are being invented, UV coated laminates to protect against aging and weather impacts are being created, variety of colors is being developed. The market offers also wooden windows with aluminium or polyvinylchloride cladding - a good combination of the positive qualities of the wood and the resistance of the aluminium and plastic to the weather impacts, corrosion etc. [Jacob 2007, Bradley 2000].

EXPERIMENT

To describe the response of the multi-chamber PVC, wooden and aluminium windows to weather during a long period of operation, it is necessary to carry out a detailed test of the impact of various factors on the parameters of the manufactured products.

Windows made of profiles of various materials were manufactured. The samples are 1480 mm x 1230 mm, with two panels – one fixed and one tilt-and-turn.

All samples have 5 locks. All sealings are made of one type of rubber (EPDM). The number of water drainage channels is also the same for all samples – 3. There are two hinges at each sample. The only difference is the type of hardware used due to the particularity of the profiles. TGP hardware is used for PVC windows, and Giesse hardware – for aluminium windows.

The frame and panels of the wooden glazed window are made of three-layer Scots pine wood of MUNCHINGER Company; finish – sealer, primer and varnish of SIKKENS Company.

Weiss Profil frame, panel and mullion profile are used for the PVC and Al windows.

To provide comparability of the results and to test the impact of the profiles, from which the windows are made, all samples are manufactured with the same type of glass unit – 24 mm (4 mm white glass / 16 air gap / 4 low emission glass) with coefficient of heat transfer Uf=1.3W/m^2.K.

All six samples are tested at Schulten stand for air permeability, wind resistance and water resistance.

- **Air permeability** EN 1026

The test consists of applying a set of standard series of tests with positive or negative pressure. At each stage is measured the airflow (Vx) passed through the sample. Air permeability (Vo) in normal conditions (To = 293 K, Po = 101.3 kPa) is given by following formula:

$$V_0 = V_x \frac{293}{273 + T_x} \cdot \frac{P_x}{101.3} \qquad \textbf{(1)}$$

where:

Tx – actual temperature expressed in degrees C;

Px – atmospheric pressure expressed in kPa.

Air permeability (Vo) is related to the length of the assembly sample (Vl) and the total area (Va) of the window. Each phase of the pressure and the vacuum is reported graphically.

- **Wind resistance** EN 12211

For the purposes of tests are made three test series with pressure (P1, P2 and P3) to determine the relative frontal bending and resistance to wind load.

- The pressure P1 is applied for measurement of the test sample bending;
- P2 is a pulse pressure of 50 cycles. It gives an indication of behaviour of samples at multiple wind load;
- P3 is applied to evaluate the safety of closing devices in the sample under extreme conditions.

The values of P1, P2 and P3 are related as follows: P2 = 0.5P1 and P3 = 1.5 P1.

- **Water tightness** EN 1027

The test consists of continuously spraying a certain amount of water on the outside of the tested samples - windows or doors, with gradually increasing pressure from

50 Pa to 300 Pa and 3000 Pa decreasing gradually to 150 Pa. The duration of each step is 1 min.

- **Sound insulation** EN ISO 10140-2.

Acoustics. Laboratory method for the measurement of airborne sound insulation of building elements such as walls, floors, doors, windows, facade elements and facades.

It is reported index of insulation of airborne noise measured in the laboratory measured by the frequency for the standard series. It is calculated by the formula:

$$R = L1 - L2 + \frac{10 \lg S}{A} dB \qquad (2)$$

where:

L1 – average sound pressure in the room of the source in decibels

L2 – average sound pressure in the room of the receiver in decibels

S – area of the test specimen in square meters, which is equal to the free hole testing

A – the relevant area of sound absorption in the room of host in square meters.

On Fig. 1 is shown an example of real measured sound reduction index R and reduce it to a standard weighted index Rw (digit value at 500 Hz curve for comparison) [Noyé 2000].

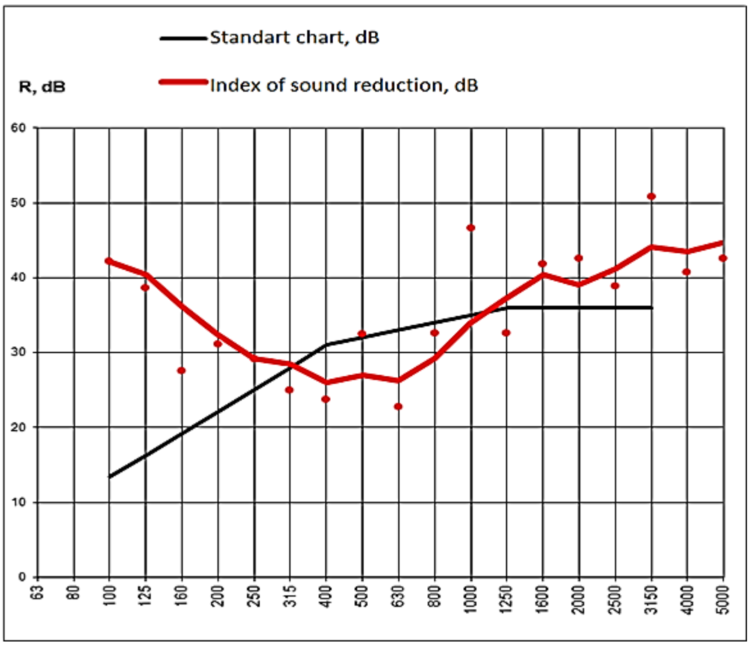

Figure 1: Index of sound reduction R, dB

- **Thermal transmittance** EN ISO 12567 – 1.

Thermal performance of windows and doors. Determination of thermal transmittance by hot box method.

Uf heat transfer through the windows is a complex process, in which three different mechanisms take part: conductivity, circulation and radiation, the direction of the heat flow is always from the room of higher temperature to the room of lower temperature. This combination of mechanisms is considered when measuring the heat transfer. The heat transfer, indicated with к and л is the ability of a material to conduct heat and it depends on the material type [Noyé 2004].

RESULTS AND DISCUSSIONS

There are six samples manufactured for testing. Three of them are made of profiles of non-plasticized polyvinylchloride – 3, 4 and 5 chambers PVC, wooden window and aluminium window with and without interrupted thermal bridge (outer and inner aluminium profile, connected with polyamide lamella). The results are shown in Table 1.

Table 1: Results of tests of various types of wood, PVC and aluminium windows

Index	Dimension	Sample 1 Wooden window	Sample 2 3-chamber. PVC window	Sample 3 4- chamber. PVC window	Sample 4 5- chamber. PVC window	Sample 5 Al window without Thermal plate	Sample 6 Al window with Thermal plate
Air permeability	Klass	4	2	3	4	2	3
Water tightness	Klass	A7	A5	A6	A7	A5	A6
Resistance to wind load	Klass	5A	4B	4C	5A	5A	5A
Sound insulation	dB	39	32	34	36	29	32
Thermal transmittance	W/m2 K	1.25	1.64	1.35	1.19	1.90	1.70

The classifications were based on national Annex to 1NA Product standard for doors and windows BS EN 14351-1, Technical Data.

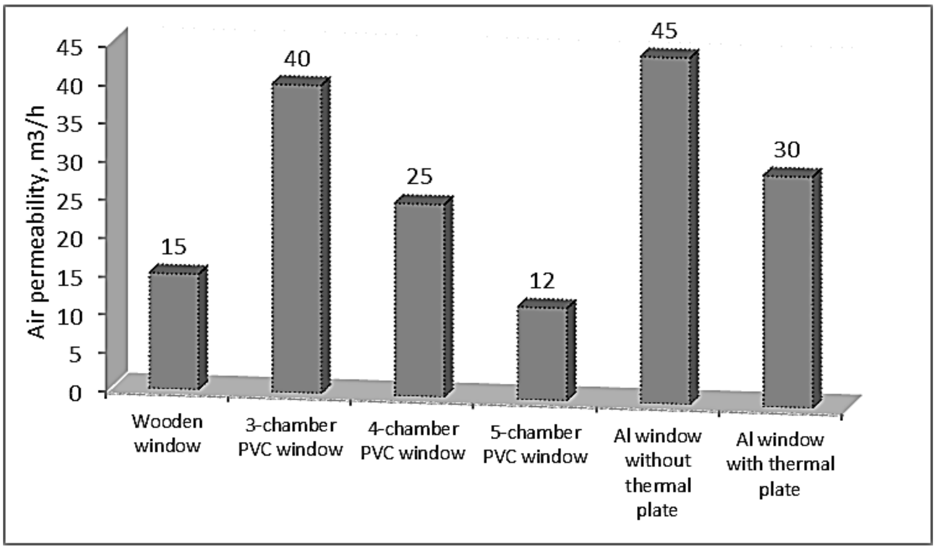

Figure 2: Comparing the air permeability in the different types of frames, m^3/h

The analysis of the test results – Fig. 2 show that the most significant air leakage (around 40–45 m^3/h) is through the aluminium window without interrupted thermal bridge and the three-chamber PVC window. The air leakage is 38 % less through the sample with the polyamide lamella and through the four-chamber PVC window. The least air leakage is through the wooden and five-chamber PVC windows – 15 m^3/h at 31.5 m/s wind speed. This is most probably due to the number of locks and the type of hardware, which depends on the profile material.

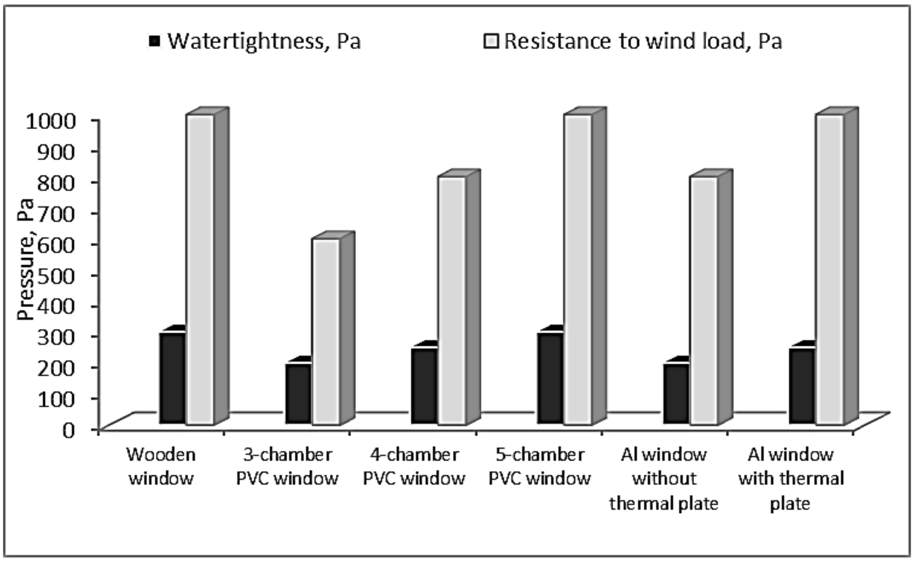

Figure 3: Water tightness and wind resistance of windows made of wood, PVC and aluminium profiles, Pa

The Fig. 3 shows that the wooden window and the five-chamber PVC window have the highest water resistance values. The water leakage has started at 300 Pa at the 50th minute after the test started. The water leakage through the four-chamber window and the aluminium window with thermal bridge has started at 250 Pa at the 40th minute. The three-chamber PVC window and the aluminium "cold" window have the lowest results – at the 35th minute and at 200 Pa pressure. The low results are due to unsuitable sealing or insufficient number of locks.

The wind resistance is equal for the wooden, five-chamber PVC and aluminium with thermal lamella windows. 20 % less is the wind resistance of the four-chamber PVC window and the aluminium "cold" window. 40 % less is the wind resistance of the three-chamber PVC window in comparison to the other types of windows tested.

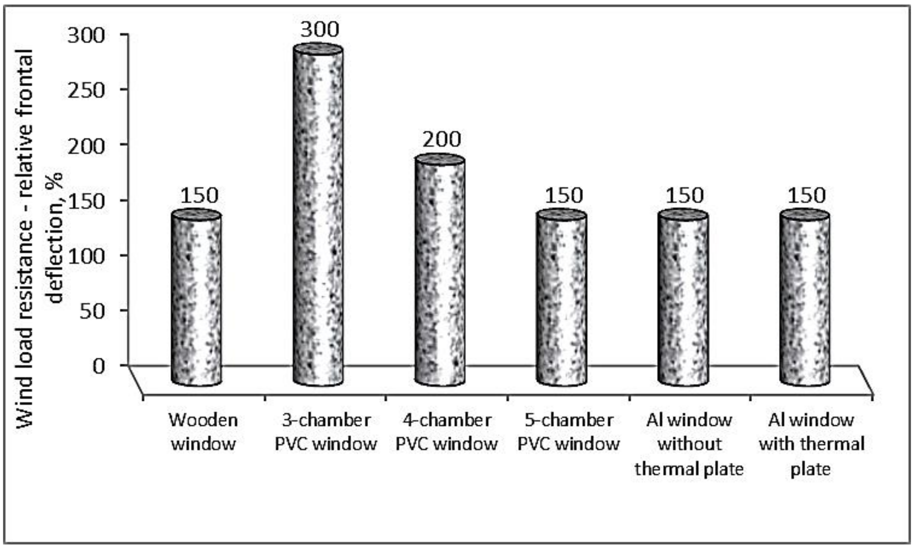

Figure 4: Relative frontal deflection on samples made of different types profiles, %

Fig. 4 shows the results for deformation of windows caused by wind load. The values of the relatively front bending show that there is no significant difference between the deformation of windows, made of wooden profiles, five-chamber PVC profiles and the two types of aluminium profiles. The bending of the four-chamber window is 25 % more. The least resistant windows to wind load are the ones made of three-chamber profile. Their bending is 50 % more than the one of the five-chamber window and the aluminium window. The results show clearly the impact of the type and geometry of the profiles on the operational parameters of the manufactured window.

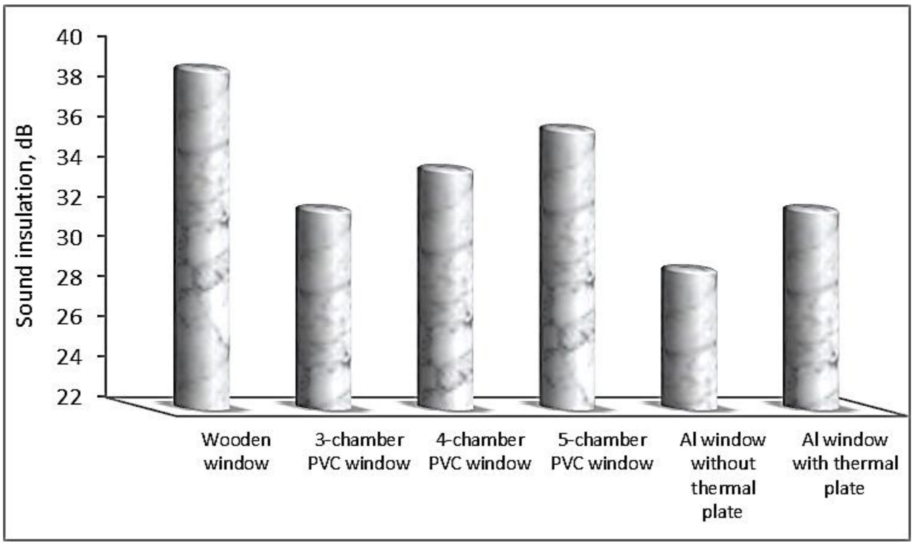

Figure 5: Sound insulation or isolation index of airborne noise measured at the windows of wood, PVC and aluminium, dB

The highest index of noise insulation is for the wooden three-layer window – 39 dB (Fig. 5). It is proved by the following results and complies with the published data [Real 2005, Wypych 2008]. The result of the five-chamber window is 36 dB, which is expected due to the number of chambers. When the number of air filled chambers decreases, the index also decreases, in other words the intensity of the sound passing through the structure increases. The noise insulation of the four-chamber sample is 34 dB, the one of the three-chamber window – 32 dB. The aluminium window without interrupted thermal bridge has the lowest index of noise insulation – 29 dB. The window with polyamide lamella lets pass 10 % less noise than the latter window.

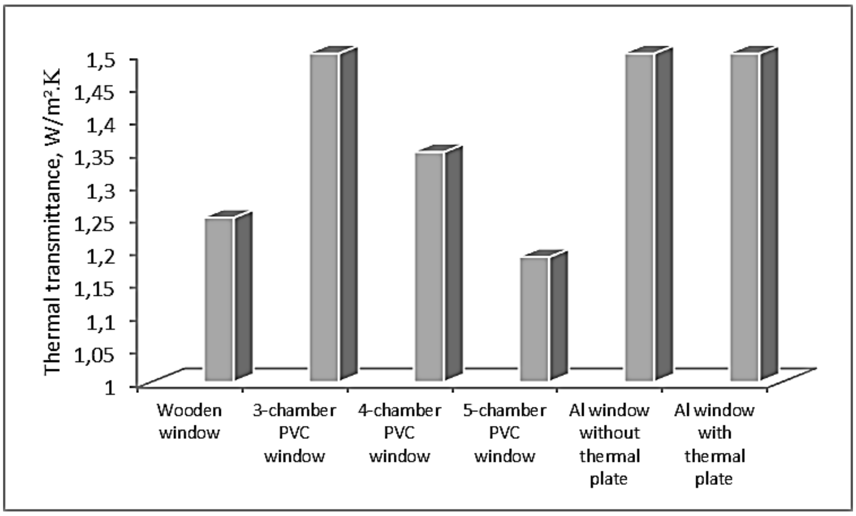

Figure 6: Thermal transmittance on wood, different types of PVC and aluminium windows, W/m^2.K

The results of the heat transfer tests show that the five-chamber window has the lowest coefficient of hear transfer – 1.19 W/m^{2}K, with 4.8 % higher is the value of the wooden sample. When the number of chambers in the PVC profiles increases the coefficient of the samples increases too. The heat transfer through the four-chamber window is 12 % higher. The value of this indicator for the three-chamber window is 1.64 W/m^{2}K, which is within the allowance, but in comparison to other PVC windows it has higher heat conductivity by 28 %.

CONCLUSION

The tests show that five-chamber PVC window has the lowest coefficient of heat transfer – 1.19 W/m^{2}K, followed by the wooden window with coefficient of 1.25 W/m^{2}K and the four-chamber PVC window with coefficient 1.35 W/m^{2}K.

The values of the heat transfer through the three-chamber PVC window are significantly higher, followed by the aluminium window with interrupted thermal bridge and aluminium “cold” one.

The noise insulation index is the highest for the wooden window. In case of the PVC window when the number of chambers increases, the noise insulation index also increases, in other words the noise transfer from outside to inside decreases.

The window frames made of aluminium profiles have a index of the order of 29–32 dB, which is consistent with literature data.

REFERENCES

1. Anton–Prinet C., G. Mur, Gay M, Audouin L. and Verdu J. (1999). Change of mechanical properties of rigid poly(vinyl chloride) during photochemical ageing. Journal of materials science, 34: 379–384.
2. Grull G., Anderl T. (2005). Wood moisture content of coated wood/aluminum windows during three years of natural weathering. Holz als Roh- und Werkstoff, 63, 5: 334–341.
3. Wegener G., Pahler A., Tratzmiller M. (2010). Bauen mit Holz = aktiver Klimaschutz. Ein Leitfaden. Holzforschung München and Technische Universität München, Munich: 8–10.
4. Gonzales K., Linera C. (2011). Energy efficient windows. Master’s Thesis, Chlamerrs University of Technology, Göteborg, Sweden:98.
5. Laustsen B. J,. Jensen C. F, Svendsen S. (2007). Calculation procedure for determination of the energy performance of windows with large glass distance, Sagsrapport, BYGDTU: 4-8.
6. Bradley, J. S. and Birta J. A. (2000). Laboratory Measurements of the Sound Insulation of Building Façade Elements. IRC Internal Report, IRC IR-818: 58–68.
7. Noyé Peter A., Svendsen S. (2000). Calculating the heat transfer coefficient of frame profiles in PVC. Department of buildings and energy. Technical university of Denmark: 6.
8. Noyé Peter A. et al. (2004). Calculating the heat transfer coefficient of frame profiles with internal cavities. Nordic Journal of Building Physics, 3: http://web.byv.kth.se/bphys/pdf/ART_0104.pdf.
9. Real, L. P., Gardette, J. L., Pereira Rocha, A. (2005). Artificial simulated and natural weathering of poly(vinyl chloride) for outdoor applications: The influence of water in the changes of properties. Polymer Degradation and Stability, 88, 33: 57–362.
10. Wypych G. (2008). PVC Degradation and stabilization. ChemTec Publishing: 128–136.