Original scientific paper
Received: 18.8.2025
Accepted: 2.7.2026
UDC: 674.21.028.1:620.17

STRENGTH OF THE CORNER JOINTS OF THE WINDOW FRAME

Elena Jevtoska, Gjorgi Gruevski, Nikola Mihajlovski

Ss, Cyril and Methodius University in Skopje, Republic of North Macedonia
Faculty of Design and Technologies of Furniture and Interior - Skopje
Email: jevtoska@fdtme.ukim.edu.mk; gruevski@fdtme.ukim.edu.mk; mihajlovski@fdtme.ukim.edu.mk

ABSTRACT

The window as a product used in construction aims to provide natural light and the possibility for ventilation in the building where it is placed but at the same time to protect the room from external influences such as wind and rain and to prevent uncontrolled cooling or heating of the building in which it is built. Given the purpose, a quality window is one that protects against air permeability and water permeability and provides wind resistance. The window is a complex product that is composed of different parts that can be made of different materials. This research is focused on the area of frame joining and joint strength. This research will cover windows made from the same PVC profile but manufactured in different production facilities. The windows will be measured for air permeability, water permeability, and wind resistance, and corner samples will be taken afterwards. The samples are prepared according to the standard EN 514:2018 Plastics - Poly (vinyl chloride) (PVC) based profiles - Determination of the strength of welded corners and T-joints.

Keywords: construction carpentry, window, air permeability, water permeability, wind resistance, PVC profiles.

1. INTRODUCTION

Today's windows are elements of construction carpentry that are composed of movable and immovable parts. Depending on the function that the windows of the building have to achieve, it is chosen from which materials they will be made and which attributes have to be met by the materials for constructing a window. If the windows are to provide only daylight in the space, they are constructed as fixed; in other words, they have only a stationary part, and if, in addition to light, they are to provide ventilation of the space, the windows are constructed with a fixed, specifically immovable case and a movable sash that, according to needs, has the possibility to open. In order to choose the most appropriate combination of materials for the construction of a quality window that will satisfy all the required functions, it is necessary to know the attributes of the built-in materials and how they affect the quality of the window.

The window as a product is a complex composition of different materials and parts. As different parts of the window, the basic structural elements, filling elements, fittings, and additional accessories are distinguished. Basic structural elements of the window are the supporting frame, the case, and the window sash.

- The supporting frame case. The supporting frame is a fixed structural element, attached to the sides of the communication opening. This case bears the window sash (Kyuchukov).
- The window sash is the moving part of the basic structural elements. Depending on the need, it can rotate along a horizontal or vertical axis, slide laterally, or do a combination of several directions of rotation.

The research will be performed on cuts from joints, specifically casing and sash angles taken from 10 windows. The examination will be on 80 samples divided into 2 groups. A group of 40 case specimens and a group of 40 sash specimens. The samples are prepared according to the standard EN

514:2018 Plastics – Poly (vinyl chloride) (PVC) based profiles - Determination of the strength of welded corners and T-joints [109]. The results of the test will give us data on the strength of the welded corners made from the same profile and how much it differs between the sash and the case.

2. MATERIALS AND METHODS

Windows from different manufacturers were taken as samples for research, using different types of hardware but made of identical frame and sash profiles. The windows will be tested for quality. In order to obtain a sufficient number of results that can be compared, the test will be carried out on ten windows made by different manufacturers. The selection of samples is that all ten samples will be made of PVC profile from the ALUPLAST brand, model IDEAL 4000.

The selected windows were initially tested for air permeability. After testing these methods, 8 samples were taken from each window, or a total of 80 samples, which were divided into two groups of 40 samples each. The first group refers to the frame samples, and the second group refers to the sash samples.

The samples were placed on a universal machine, and a compressive force F was applied to them. At the moment of failure of the joint, the applied force was recorded.

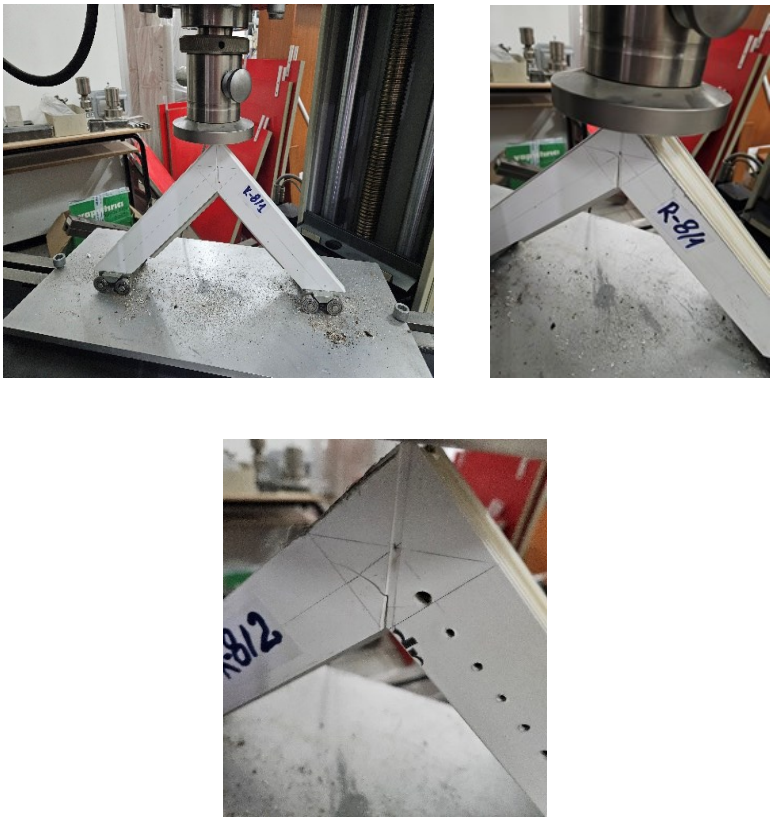


Figure 1. *Force action on samples from a frame group.*



Figure 2. *Force action on samples from a sash group.*

3. RESULTS AND DISCUSSION

3.1. Results of the air permeability

3.1.1. Results – air permeability

Table 1. *Sample 1 – air permeability.*

P_a normal		50	100	150	200	250	300	450	600	
P_a actual		49	100	150	200	250	302	453	600	
Air permeability	m³/h	15.88	24.81	33.03	42.15	52.42	64.59	113.69	175.56	General class
Perimeter	m³/(h/m)	2.74	4.28	5.69	7.27	9.04	11.14	19.60	30.27	
Class		2	2	2	2	2	2	0	0	2
Window surface	m³/(h/m²)	8.49	13.27	17.66	22.54	28.03	34.54	60.79	93.98	
Class		2	2	2	2	2	2	0	0	2
										2

Table 2. *Sample 2 – air permeability.*

P_a normal		50	100	150	200	250	300	450	600	
P_a actual		49	102	150	201	251	303	451	596	
Air permeability	m³/h	14.18	23.37	30.97	38.14	45.32	52.43	75.07	100.15	General class
Perimeter	m³/(h/m)	2.26	3.59	4.71	5.80	6.90	7.98	11.43	15.24	
Class		2	2	2	2	2	2	0	0	2
Window surface	m³/(h/m²)	7.57	11.92	15.80	19.46	23.12	26.75	38.30	51.10	
Class		2	2	2	2	2	2	0	0	2
										2

Table 3. *Sample 3 – air permeability.*

P_a normal		50	100	150	200	250	300	450	600	
P_a actual		51	101	149	201	251	300	451	598	
Air permeability	m³/h	14.82	23.20	30.78	38.14	45.33	52.45	75.30	100.38	General class
Perimeter	m³/(h/m)	2.24	3.53	4.73	5.80	6.90	7.97	11.46	15.29	
Class		2	2	2	2	2	2	0	0	2
Window surface	m³/(h/m²)	7.55	11.90	15.78	19.46	23.12	26.76	38.33	51.13	
Class		2	2	2	2	2	2	0	0	2
										2

Table 4. *Sample 4 – air permeability.*

P_a normal		50	100	150	200	250	300	450	600	
P_a actual		50	100	150	201	251	301	454	604	
Air permeability	m³/h	2.07	3.22	4.13	4.93	5.60	6.20	7.86	9.38	General class
Perimeter	m³/(h/m)	0.50	0.79	1.01	1.20	1.36	1.51	1.92	2.29	
Class		3	3	3	3	4	4	4	4	3
Window surface	m³/(h/m²)	1.82	2.82	3.62	4.32	4.91	5.44	6.89	8.23	
Class		4	4	4	4	4	4	4	4	4
										4

Table 5. *Sample 5 – air permeability.*

P_a normal		50	100	150	200	250	300	450	600	
P_a actual		50	101	150	200	251	301	452	604	
Air permeability	m³/h	7.23	10.77	14.09	16.66	18.92	21.00	26.25	30.97	General class
Perimeter	m³/(h/m)	1.29	1.93	2.52	2.99	3.39	3.76	4.70	5.55	
Class		3	3	3	3	3	3	3	3	3
Window surface	m³/(h/m²)	5.56	8.28	10.84	12.81	14.55	16.16	20.19	23.82	
Class		3	3	3	3	3	3	3	3	3
										3

Table 6. *Sample 6 – air permeability.*

P_a normal		50	100	150	200	250	300	450	600	
P_a actual		52	102	150	202	251	302	451	604	
Air permeability	m³/h	1.31	2.10	2.78	3.41	4.00	4.55	6.20	7.87	General class
Perimeter	m³/(h/m)	0.36	0.57	0.76	0.93	.09	1.24	1.70	2.15	
Class		4	4	4	4	4	4	4	4	4
Window surface	m³/(h/m²)	1.37	2.19	2.90	3.55	4.17	4.74	6.46	8.19	
Class		4	4	4	4	4	4	4	4	4
										4

Table 7. *Sample 7 – air permeability.*

P_a normal		50	100	150	200	250	300	450	600	
P_a actual		50	100	150	201	251	300	453	601	
Air permeability	m³/h	3.15	4.93	6.51	8.56	10.76	13.46	26.25	43.81	General class
Perimeter	m³/(h/m)	0.86	1.34	1.77	2.33	2.93	3.67	7.15	11.94	
Class		3	3	3	3	3	3	0	0	2
Window surface	m³/(h/m²)	3.28	5.13	6.78	8.91	11.21	14.02	27.34	45.63	
Class		3	3	3	3	3	3	0	0	2
										2

Table 8. *Sample 8 – air permeability.*

P_a normal		50	100	150	200	250	300	450	600	
P_a actual		50	100	150	202	251	302	453	603	
Air permeability	m³/h	0.88	1.65	2.20	2.66	3.07	3.47	4.58	5.93	General class
Perimeter	m³/(h/m)	0.22	0.41	0.54	0.66	0.76	0.86	1.13	1.46	
Class		4	4	4	4	4	4	4	4	4
Window surface	m³/(h/m²)	0.78	1.47	1.96	2.37	2.74	3.10	4.09	5.30	
Class		4	4	4	4	4	4	4	4	4
										4

Table 9. *Sample 9 – air permeability.*

P_a normal		50	100	150	200	250	300	450	600	
P_a actual		51	100	151	201	251	303	451	603	
Air permeability	m³/h	2.20	3.42	4.41	5.20	5.92	6.55	7.96	8.84	General class
Perimeter	m³/(h/m)	0.78	1.20	1.55	1.83	2.08	2.31	2.80	3.11	
Class		3	3	3	3	3	3	3	3	3
Window surface	m³/(h/m²)	3.49	5.42	6.99	8.26	9.39	10.40	12.64	14.04	
Class		3	3	3	3	3	3	3	3	3
										3

Table 10. *Sample 10 – air permeability.*

P_a normal		50	100	150	200	250	300	450	600	
P_a actual		50	100	150	200	250	301	451	603	
Air permeability	m³/h	1.45	2.40	3.14	3.80	4.39	4.95	6.72	9.02	General class
Perimeter	m³/(h/m)	0.38	0.63	0.82	1.00	1.15	1.30	1.74	2.37	
Class		4	4	4	4	4	4	4	4	4
Window surface	m³/(h/m²)	1.30	2.14	2.80	3.39	3.92	4.42	6.00	8.06	
Class		4	4	4	4	4	4	4	4	4
										4

3.2. Results from windows made from the same identical profile, determining the strength of the corner joints of the frame (sash, frame)

3.2.1. Results from a group of sash tests

Window number	**Simple number**	**F (N)**	**Mean Value – F (N)**
1	**1**	5279 N	F_1 = 5180 N
	2	5121 N	
	3	5278 N	
	4	5042 N	
2	**1**	4305 N	F_2 = 4255 N
	2	4284 N	
	3	4118 N	
	4	4311 N	
3	**1**	4825 N	F_3 = 4863 N
	2	4903 N	
	3	4911 N	
	4	4813 N	

4	**1**	5744 N	F_4 = 5727 N
	2	5707 N	
	3	5709 N	
	4	5748 N	
5	**1**	5413 N	F_5 = 5408 N
	2	5419 N	
	3	5395 N	
	4	5403 N	
6	**1**	5863 N	F_6 = 5672 N
	2	5312 N	
	3	5780 N	
	4	5733 N	
7	**1**	4388 N	F_7 = 4362 N
	2	4361 N	
	3	4313 N	
	4	4387 N	
8	**1**	5713 N	F_8 = 5616 N
	2	5648 N	
	3	5511 N	
	4	5593 N	
9	**1**	4813 N	F_9 = 4870 N
	2	4915 N	
	3	4889 N	
	4	4864 N	
10	**1**	5763 N	F_{10} = 5743 N
	2	5711 N	
	3	5784 N	
	4	5717 N	

3.2.2. Results from a group of frame tests

Window number	**Simple number**	**F (N)**	**Mean Value – F (N)**
1	**1**	4796 N	F_1 = 4891 N
	2	4851 N	
	3	4013 N	
	4	4904 N	
2	**1**	4881 N	F_2 = 4894 N
	2	4903N	
	3	4874 N	
	4	4918 N	
3	**1**	4987 N	F_3 = 4935 N
	2	4913 N	
	3	4893 N	

	4	4948 N	
4	**1**	5250 N	F_4 = 5151 N
	2	5098 N	
	3	5112 N	
	4	5144 N	
5	**1**	5010 N	F_5 = 5050 N
	2	5108 N	
	3	5970 N	
	4	5112 N	
6	**1**	4980 N	F_6 = 5388 N
	2	5725 N	
	3	5041 N	
	4	5804 N	
7	**1**	4613 N	F_7 = 4819 N
	2	4985 N	
	3	4913 N	
	4	4764 N	
8	**1**	5290 N	F_8 = 5293 N
	2	5311 N	
	3	5301 N	
	4	5270 N	
9	**1**	4968 N	F_9 = 4946 N
	2	4915 N	
	3	4977 N	
	4	4815 N	
10	**1**	5014 N	F_{10} = 5119 N
	2	5096 N	
	3	5312 N	
	4	5054 N	

CONCLUSIONS

In this research, the obtained results were used for comparison with the results of air permeability obtained from the strength of the joints of the case and the sash.

The profile that is used for making windows has a minimal influence on the air permeability of the window.

The construction of the window has a significantly large influence on the frontal deviations during the wind load.

The same profile assembled in a different production capacity gives different joint strength results.

The strength of the joint and the frame has an impact on the air permeability of the window. The corner joint of the frame and the sash is one part of the window construction that affects the final quality of the window.

REFERENCES

[1] Кучуков, Г., Конструиране на мебели, врати и прозорци, 2009, Матком, Софија.

[2] Postowa, P., (2017), Strength analysis of welded corners of PVC window profiles, IOP Conference Seres: Materials and Engineering.
[3] EN 1026:2016 “Windows and doors - Air permeability - Test method” standard.
[4] EN 1027:2016 “Windows and doors - Water tightness - Test method” standard.
[5] EN 12211:2016 "Windows and doors - Resistance to wind load - Test method" standard.
[6] EN 514:2018 Plastics - Poly(vinyl chloride) (PVC) based profiles - Determination of the strength of welded corners and T-joints.
[7] https://www.aluplast.net/eng-int/produkte/fenster/ideal/ideal-4000/ пристапено на 14-04-2025 год.
[8] Gruevski,T., Simakoski, N. (2002): Elementi na drvnite konstrukcii, Skopje: UKIM Shumarski fakultet.
[9] Gruevski,T., Simakoski, N. (2003): Konstruiranje na mebel, Skopje: UKIM Shumarski fakultet.
[10] Zakon za energetska efikasnost (2020): Sluzben vesnik na Republika Makedonija, br.32/2020 od 09-02-2020 god.
[11] Zakon za gradezni proizvodi (2015): Sluzben vesnik na Republika Makedonija, br.104/2015 od 24-06-2020 god.
[12] Ibrahimovic, E., Kljuno, H.A. Window frame materials and window size: parametesrs that influence enegy efficiency in buildings. Technics technologies education management.

Author’s address

Dr Elena Jevtoska, PhD, assistant professor.
Dr Gjorgi Gruevski, PhD, full professor.
Dr Nikola Mihajlovski, PhD, assistant professor.
Ss. Cyril and Methodius University in Skopje,
Faculty of Design and Technologies of Furniture and Interior – Skopje,
16ta Makedonska brigada 3,
1000 Skopje, Republic of North Macedonia.