

## Studies on Some Properties of Quality and Performance in Wood Windows

<sup>1</sup>Tuncer Dilik <sup>2</sup>Barış Altun

<sup>1</sup>Istanbul University Faculty of Forestry, Department of Forest Industry Engineering 34473  
Bahcekoy/Istanbul, Turkey

<sup>2</sup>Asil Ahşap Joint-stock Company, Haramidere, Istanbul, Turkey

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**Abstract:** The determination of some quality and performance properties of windows, made of tree species used frequently in industrial window manufacturing and the effects of tree species on those properties have been examined. According to the results of the study by considering regular standards, in the air resistance tests, the classification has been determined as follows: those made of Scots pine as (*Pinus sylvestris*) A4, European larch (*Larix decidua*) as A3 and Sapele (*Entandrophragma cylindricum*) as A2. The water resistance test has classified those made of Scots pine (*Pinus sylvestris*) as in between RA6 and RA7, European Larch (*Larix decidua*) as in between RA1 and RA3 and Sapele (*Entandrophragma cylindricum*) as RA1. As for wind resistance test, all species have been found in the class W5. When having made the same test in PVC for the purpose of controlling and making comparison and to verify the outcomes obtained from regular test, it was found that air permeability was A4, water tightness was RA9 and wind resistance test was W5. As can be seen from the given results, PVC has proved to show best performance among all, whereas Scots pine samples has shown the the best performance among all the other wood products followed by European Larch and Sapele. The reasons for that are the woodworking and workmanship quality rather than changeable physical, mechanical and technical properties of the wood species.

**Key words:** Wood window, air permeability, water tightness, wind resistance, withstand wind load

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### INTRODUCTION

Researches made on the production of window components from different materials shows that most of the users prefer the ones out of wooden, aluminum and PVC (plastic materials). The tendency towards the preference rate of the products from these materials indicates us it has been the plastic materials that is mostly preferred recently<sup>[1]</sup>.

Since it has technological, physical and mechanical properties as raw material and furniture; moreover, it is a renewable material, wood is used in window production as an irreplaceable component. However, the use of wooden materials has given way to PVC and aluminum alloys these days due to its diminishing resources and increasing economic problems along with troubles in quality and performance.

Nowadays, increasing quality of life has enabled us to choose the more quality and different choices among the equipment elements in reshaping the common human habitats. In this reshaping, with the many fitting components, joinery things are also used and they

account for a remarkable group. Joinery products like doors and windows not only provide people a comfort but also some vital needs such as heating and security. For instance, those products are to serve as a connector between air, light, sound, visual relations and outside; in addition, it must provide the isolation, control and security at the same time. Therefore, there are a lot of factors in choosing joinery materials and appropriate construction like security, controlling, isolation, architectural aesthetics and cost<sup>[2-5]</sup>.

Wood windows studied in a research should bear some important properties mentioned above like resistance to cold-hot, extreme sun light and being economical, diminishing the outside sounds, easy to be cleaned and maintained. Appropriate properties for purpose of use, hence, should be taken into consideration in designing the joinery and material selection and production<sup>[3]</sup>.

From this point of view, historical buildings stand for good examples in that they have remained healthy for years and functioned it did before with the right care and material selection. On the other hand, diminishing

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**Corresponding Author:** Assist. Prof. Dr. Tuncer Dilik, Istanbul University Faculty of Forestry, Department of Forest Industry Engineering 34473 Bahcekoy/Istanbul, Turkey, Tel: +90 212 226 11 00, Fax: +90 212 226 11 13

forests and its high cost lead us to a rational use of that material and make it more and more important, which puts forward the importance of manufacturing industrial wooden window<sup>[5]</sup>.

**Quality and performance tests in windows:** Changing conditions of our time requires quality and performance tests both to provide sustainability in obtaining the product with the same quality and to control the appropriate performance properties as in all areas. Moreover, its benefits like increasing the value of the product in the market creating differences from the manufacturer's competitors, contribution to the product development and enabling the user to use it with confidence emphasize the importance of those tests.

Both national and international, there are various standards for quality and performance properties of windows. And in those in our country are regulated by the Institute of Turkish Standards. Some examples to those tests are as follows;

- a- TS 7251 EN- Methods of testing windows; Mechanical test
- b- TS EN 1191-Windows and doors- Resistance to repeated opening and closing
- c- TS EN 1027/T1-Windows and doors - Water tightness - Test method
- d- TS EN 1026-Windows and doors - Air permeability - Test method
- e- TS EN 12207 -Windows and doors-Air permeability-Classification
- f- TS4644 EN 12211-Windows and doors - resistance to wind load – classification
- g- TS EN 12208-Windows and doors-Water tightness-Classification
- h- SEN ISO12567-1-Thermal performance of windows, doors and shutters- Calculation of thermal transmittance- Part 1: Simplified method (ISO 10077-1:2000)
- i- TS EN 14608-Windows - Determination of the resistance to racking
- j- TS EN 14609-Windows - Determination of the resistance to static torsion
- g- TSEN13049-Windows-Soft and heavy body impact-Test method, safety requirements and classification

It is frequently seen that those standards, which are not required by law, are applied in the production of windows from materials apart from wooden ones (PVC, aluminum, etc) as these materials turn the disadvantages of wood in terms of form and material itself into an advantage with quality and performance properties. On the other hand, not using advanced

technologies in our country in wood window production can be given as a reason for ignoring those standards.

In this study, of the tests determined by regulations and standards, air permeability, water tightness and wind resistance tests, which play vital role in quality and performance, are explained.

**Air permeability test:** This test is based on measuring of the airloss in a vacuumed atmosphere, with the same air and pressure conditions, regarding the selected tree species, on the m<sup>3</sup>/h scale. Therefore, airloss is defined as the amount of air leaked per hour on m<sup>3</sup> scale<sup>[6]</sup>. To the EN 1026 standards, window classifications and expected amount of airloss is given below on the Table 1.

**Water tightness:** This is based on the principle of observing which part of the window gives out the water leakages as drops and flows under the pressure. The degree of pressure when water leakage occurs determines the class of the window<sup>[7]</sup>. Those classified according to these standards are given below on Table 2.

This test is applied with two spraying units aiming at the window with the angle of 24 degree and each unit is 40 cm away from each other spraying 3 liters water per minute behind the window (outside the building). During this process, test is completed when water leakages observed on the window turns into drops and those drops become flows and when these two phases are marked.

**Wind resistance (Withstand wind loads):** It is based on the principle of measuring the bending rate on the mullions profile and permanent deformation after the pressure on the windows, from selected class and predetermined pressure, with at least a mullion using digital micrometers. In addition to this, it is observed whether the high pressure applied during the test has caused any damage on window glasses and other accessories<sup>[8]</sup>. Those classified to this standard are given below on the Table 3.

Its class is the one determined after withstand wind loads without permanent deformation. To determine this, W5, the highest class, should be chosen, if permanent deformation occurs after the window has passed the first security test (2200 Pa), one class lower window should be chosen. In this study, all the resistance tests are applied using W5 class without needing any lower class.

Table 1: Window classifications determined by air permeability test and desired air losses (EN 1026:2000)

Window class	The highest pressure applied (Pa)	Airloss in per scope (m <sup>3</sup> /h)	Airloss in the length of seal used per scope (m <sup>3</sup> /h)
A0	100	$x > 50$	$x > 12,5$
A1	100	$25 < x < 50$	$6 < x < 12,5$
A2	300	$18 < x < 67$	$4 < x < 14$
A3	600	$10 < x < 30$	$2,5 < x < 7,5$
A4	600	$X < 10$	$x < 2,5$

Table 2: Window classifications determined by water tightness test (EN1027:2000)

Window Class	Leakages according to pressure degree	
RA0	When no pressure	Leakage present
RA1	No leakage when lacking pressure	leakage at 50 Pa
RA2	No water leakage at 50 Pa	leakage at 100 Pa
RA3	No water leakage at 100 Pa	leakage at 150 Pa
RA4	No water leakage at 150 Pa	leakage at 200 Pa
RA5	No water leakage at 200 Pa	leakage at 250 Pa
RA6	No water leakage at 250 Pa	leakage at 300 Pa
RA7	No water leakage at 300	leakage at 450 Pa
RA8	No water leakage at 450 Pa	leakage at 600 Pa
RA9	No water leakage at 600 Pa	No leakage

Table 3: Window classifications determined by withstand wind load test (EN 12211:2000)

Window classes	Pressure intervals
W1	400 Pa
W2	800 Pa
W3	1200 Pa
W4	1600 Pa
W5	2000 Pa

In withstand wind loads, P1=2000 Pa, P2=1000 Pa and P3=3000 different pressure types are used. Before P1 is applied, 10% more of it, 2200 Pa is applied both in pressure form and in vacuum form three times with 7 seconds periods and this determines whether a lower class is needed according to the permanent deformation following this test.

### MATERIAL AND METHOD

In this study, windows made from three different laminated timber, Scots pine and European larch from softwoods and Sapele from hardwoods and PVC windows are used (Fig. 1)<sup>[9,10]</sup>.

**Technical properties of the windows in tests:** The profiles of the wood windows used in tests are 68 X 80 mm and they are jointed through the method of “tongue and groove” (Scots pine and European larch) and miter joint (Sapele) which are frequently used in window manufacturing. Those windows are manufactured with one casement window, a mullion profile, having two hinges and tilt turn window fittings (Fig. 1).

In testing device used, windows with the size of, at least, 1000 x 1000 mm can be tested. Therefore, all the wooden window samples tested are produced in this size.

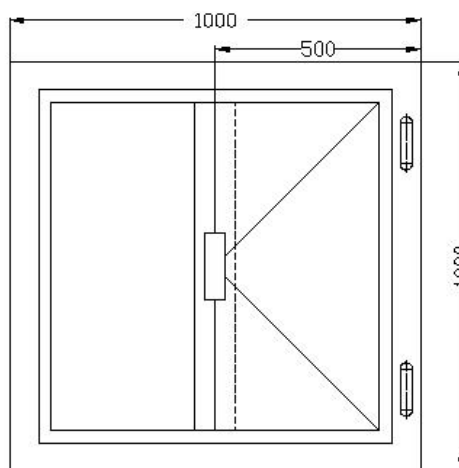


Fig. 1: The sizes of laminated wood window samples used in the tests

EPDM (Ethylene Propylene Diene Monomer) seal is used in the window frame and casement window of both the wood windows and the PVC ones as weatherseals. Double hinges in the samples of Sapele, European larch and PVC. As for the ones from Scots pine, secret hinge is used. Insulating glass is selected as glass type. Double glazing used in all windows, the thickness is 4 cm and the gap between two glasses is 12 mm<sup>[11]</sup>.

As a locking mechanism, espagnolette bolt for turn only windows widely preferred in industrial window production is used; in PVC windows, tilt and turn window fittings is used<sup>[12]</sup>.

In the sample made out of Sapele, a drainage sash is carved into the sample; in the European Larch, a drainage sash with two holes of 5 mm diameter, made out of aluminum, is used; and in Scots pine samples, the same type of aluminum channel with two holes 5 mm in width and 30 mm in length is used as water drainage systems. As for the PVC, it is carved in the drainage sash in different angles.

Wood windows samples are tested with all fittings on them and all surface finishing done.

In the study, air permeability (EN 1026:2000), water tightness (EN 1027:2000) and wind resistance (EN 12211:2000) tests on three different tree species and PVC products have been applied regarding the

Table 4: The results of air permeability test on PVC windows samples)

Pressure (Pa)	Per scope (m <sup>2</sup> )		To the seal length (m)	
	Air loss m <sup>3</sup> /h	Window classes	Air loss m <sup>3</sup> /h	Window classes
50	0.96	A4	0.23	A4
100	1.35	A4	0.32	A4
150	1.58	A4	0.37	A4
200	1.77	A4	0.42	A4
250	1.99	A4	0.47	A4
300	2.18	A4	0.52	A4
450	2.71	A4	0.64	A4
600	3.25	A4	0.77	A4
-50	1.13	A4	0.27	A4
-100	1.40	A4	0.33	A4
-150	1.63	A4	0.39	A4
-200	1.83	A4	0.43	A4
-250	2.05	A4	0.49	A4
-300	2.23	A4	0.53	A4
-450	2.77	A4	0.66	A4
-600	3.29	A4	0.78	A4

Table 5: The results of air permeability test on windows samples from Sapele

Pressure (Pa)	Per scope (m <sup>2</sup> )		To the seal length (m)	
	Air loss m <sup>3</sup> /h	Window classes	Air loss m <sup>3</sup> /h	Window classes
50	7.05	A2	2.07	A2
100	10.89	A2	3.20	A2
150	14.06	A2	4.13	A2
200	16.54	A2	4.86	A2
250	19.33	A2	5.68	A2
300	22.83	A2	6.71	A2
450	36.64	A2	10.78	A2
600	51.45	A2	15.13	A2
-50	5.85	A2	1.72	A2
-100	8.47	A3	2.49	A2
-150	10.34	A3	3.04	A2
-200	11.77	A3	3.46	A3
-250	15.83	A3	4.66	A2
-300	16.24	A3	4.78	A2
-450	17.37	A3	5.11	A3
-600	20.23	A3	5.95	A3

related standards. Taking the results into consideration, it is aimed to determine the effects of tree species on the functions.

Trials done at Asaspen Joint -stock company were conducted via a testing device under the control of a computer having software called “WACS Release 8 Version”, applying three tests subsequently.

### RESULTS

In this study, results have been released referring to those of one sample from each species.

**Air permeability:** The purpose of air permeability is to test the weatherseal, glazing bead and hinges used at the casement window, where air loss is more likely. Hence, quality of the seals used in window manufacturing,

their fitting quality, proper hinges adjustments and suitable production of the glazing bead and their right fittings come to the forth.

As can be seen in the Table 4, PVC windows showed much better performance comparing with the wooden ones regarding the materials of the testing samples (Table 4). Very little air loss is observed mostly due to the seal on the casement window. The air permeability class of the PVC window is defined as A4.

During testing the sample from Sapele, air loss from 50 pa to 300 pa, especially at the pressure of 400 and 600 pa, increases from glazing beads and casement window hinges (Table 5). Miter joint at the corners used in this sample showed no air loss. Furthermore, in the sample examined after the test, it is observed that openings occurred at the weatherseals facing the corners, used on the casement windows, no proper

Table 6: The results of air permeability test on windows samples from European larch

Pressure (Pa)	Per scope (m <sup>2</sup> )		To the seal length (m)	
	Air loss m <sup>3</sup> /h	Window classes	Air loss m <sup>3</sup> /h	Window classes
50	3.90	A3	1.15	A3
100	6.09	A3	1.79	A3
150	7.80	A3	2.29	A3
200	9.20	A3	2.70	A3
250	10.43	A3	3.07	A3
300	11.43	A3	3.36	A3
450	14.44	A3	4.25	A3
600	16.55	A3	4.87	A3
-50	4.16	A3	1.22	A3
-100	6.32	A3	1.86	A3
-150	8.00	A3	2.35	A3
-200	9.40	A3	2.76	A3
-250	10.61	A3	3.12	A3
-300	11.64	A3	3.42	A3
-450	16.30	A3	4.79	A3
-600	17.12	A3	5.04	A3

Table 7: The results of air permeability test on windows samples from Scots pine

Pressure (Pa)	Per scope (m <sup>2</sup> )		To the seal length (m)	
	Air loss m <sup>3</sup> /h	Window classes	Air loss m <sup>3</sup> /h	Window classes
50	1.43	A4	0.28	A4
100	2.19	A4	0.42	A4
150	2.47	A4	0.48	A4
200	2.71	A4	0.52	A4
250	2.93	A4	0.57	A4
300	3.21	A4	0.62	A4
450	3.93	A4	0.76	A4
600	4.81	A4	0.93	A4
-50	1.96	A4	0.38	A4
-100	2.55	A4	0.49	A4
-150	3.10	A4	0.60	A4
-200	3.59	A4	0.69	A4
-250	4.09	A4	0.79	A4
-300	4.57	A4	0.88	A4
-450	6.35	A4	1.23	A4
-600	8.75	A4	1.69	A4

Table 8: The results of water tightness test on PVC window

Pressure (Pa)	Time (minute)	Situation	Window class
0	15	No problem	RA9
50	5	No problem	
100	5	No problem	
150	5	No problem	
200	5	No problem	
250	5	No problem	
300	5	No problem	
450	5	No problem	
600	5	No problem	

fitting was provided and that the edges of EPDM seals facing the corners of the casement window had been cut caused decrease in their resistance to air loss. In addition, it can be said that the glazing bead below was not really fit and, in the other windows, air loss occurred as the silicone providing impermeability

between the glazing bead and glass was not used in this sample. The air permeability of the sample from Sapele is defined as A2.

In both samples from European larch, it was observed that the air loss happened on the hinges and assembling points. As the samples were examined, the adjustment screws of the hinges were not properly tightened. Within the corner mounting type used in this sample, tongue and groove, it was seen that the corners were not well fit, causing bad seal fitting quality; as a result, around these sections existed air loss. On the other hand, the impermeability in this sample is in better condition than that in Sapele. Air permeability of European larch is A3 (Table 6).

As for the samples from Scots pine, air loss stemmed from glazing bead manufactured improperly; nevertheless, it can be said that the values were higher

Table 9: The results of water tightness test on windows from Sapele

Pressure (Pa)	Time (minute)	Situation	Window class
0	15	No problem	RA1
50	5	Dropping	
100	5	Dropping	
150	5	Dropping	
200	5	Dropping	
250	5	Dropping	
300	5	Dropping	
450	5	Flow	
600	5	Flow	

Table 10: The results of water tightness test on windows of Scots pine

Pressure (Pa)	Time (minute)	Situation	Window class
0	15	Flow	RA3
50	5	Flow	
100	5	Flow	
150	5	Dropping	
200	5	Dropping	
250	5	Dropping	
300	5	Dropping	
450	5	Flow	
600	5	Flow	

Table 11: The results of water tightness test on windows of Scots pine

Pressure (Pa)	Time (minute)	Situation	Window class
0	15	No problem	RA7
50	5	No problem	
100	5	No problem	
150	5	No problem	
200	5	No problem	
250	5	No problem	
300	5	No problem	
450	5	Dropping	
600	5	Flow	

Table 12: The results of withstand wind load test of PVC window

Pressure (Pa) (P1)	Withstand wind load (mm)		
	1 <sup>st</sup> sensor (min)	2 <sup>nd</sup> sensor (average)	3 <sup>rd</sup> sensor (max)
2000	2.1	4.9	2.3
0	0	0	0
-2000	-1.4	-4.4	-2.7
0	0	0	0

than Sapele and European Larch. In these samples, no air loss from jointed window frames was observed. In addition, workmanship and assembling quality of the Scots Pine samples checked after tests were better than the other windows. Air permeability of the samples from Scots pine is determined A4 class (Table 7).

Air permeability classes of Scots pine with secret seal are much higher than the other samples as regard to seal types used.

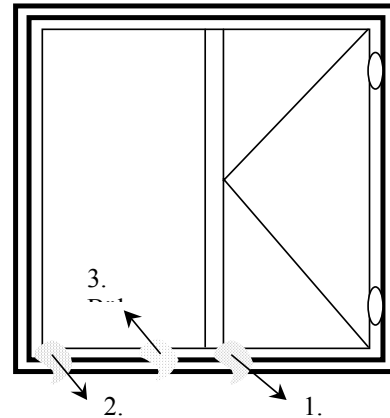


Fig. 2: The zones where leakages were observed in the water tightness test of the window samples from Sapele

**Water tightness:** As we all know, windows are the construction units that are more liable to outside weather conditions compared to the others. In this test, with the testing device window sample is fit in, isolation system in windows is tested creating an atmosphere like outside weather conditions. For this purpose, a kind of rain effect is created, its intensity increasing gradually and water leakages in windows are observed. Below are the results of water tightness assessed in a table and given in an order of PVC, Sapele, European larch and Scots pine.

PVC showed no water leakage after the tests. This can certainly be due to the good design of isolation system. Using plastic seal in glazing bead can be a good proof for that. Also, that tilt and turn window fittings and hinges adjustments are done properly affected the test results positively (Table 8). Water tightness of PVC is defined as RA9.

During the test of Sapele (Table 9), no water was let in under no pressure. But under the pressure of 50 Pa, water leakage from left corner below was seen as drops (Fig. 2; zone 1). When it reached 150 Pa, left corner below of the steady side (Fig. 2; zone 2); after 250 pa, from the glazing bead, the leakage was recorded as drops. This went on until the drops turned into flow at the pressure of 450 Pa. Here, it can be said that leakage from the glazing bead occurred at the points where the lath was in contact with both the glass and the wood frame.

Examinations after the test, leakages in Fig. 2 may have happened due to the fact that edge sides of the seals had been cut and these sides hadn't been adhered to the wood frame. As for the leakages from the glazing bead, they were due to insufficient fitting of bead.

Table 13: In the withstand wind loads of PVC window, results of air permeability test after P2 pressure

Pressure (Pa)	Per scope (m <sup>2</sup> )			To the seal length (m)		
	Air loss m <sup>3</sup> /h	Widow class	Difference to the 1 <sup>st</sup> test	Air loss m <sup>3</sup> /h	Widow classes	Difference to the 1 <sup>st</sup> test
50	1.00	A4	0.040	0.24	A4	0.010
100	1.36	A4	0.005	0.32	A4	0.001
150	1.59	A4	0.010	0.38	A4	0.002
200	3.10	A4	0.064	0.43	A4	0.015
250	3.40	A4	0.022	0.48	A4	0.005
300	3.72	A4	0.023	0.52	A4	0.005
450	4.58	A4	0.007	0.64	A4	0.002
600	5.52	A4	0.020	0.77	A4	0.005
-50	1.91	A4	0.005	0.27	A4	0.001
-100	2.37	A4	0.007	0.33	A4	0.002
-150	2.77	A4	0.011	0.39	A4	0.003
-200	3.12	A4	0.018	0.44	A4	0.004
-250	3.48	A4	0.008	0.49	A4	0.002
-300	3.75	A4	0.013	0.53	A4	0.003
-450	4.66	A4	0.008	0.65	A4	0.002
-600	5.62	A4	0.036	0.79	A4	0.009

Table 14: The results of withstand wind load test of Scots pine window

Pressure (Pa) (P1)	Withstand wind load (mm)		
	1 <sup>st</sup> sensor (min)	2 <sup>nd</sup> sensor (min)	3 <sup>rd</sup> sensor (min)
2000	0	0	0
0	0	0	0
-2000	0	-0.3	-0.2
0	0	0	0

Not using silicone between glass and glazing bead could be the reason for the leakages from these zones, just in this type of frame. By the way, it should be mentioned that water drainage sash was sufficient. Water tightness value of sample from Sapele is recorded RA1.

In the samples of European larch (Table 10), leakage drops started at the casement window under 150 pa (Fig. 3; zone 1) and when it reached 300 pa, glazing bead also started leaking. The same zones turned the drops into a flow under the pressure of 450 Pa (Fig.3). After test examination showed that holes in the drainage sashes were not efficient. Also, it was seen that aluminum channel was produced improperly; in other words, there were openings at the zones where the channel was in contact with mullion profile and hinge stile, leading leakages. The leakages in glazing bead occurred at the zones where the contact between bead and window frame existed as in other wood samples. Silicone at the zones where the contact between glazing bead and glass existed may have prevented the leakage. Sample from European larch is classified RA3.

Scots pine samples (Table 11) started the drops under the pressure of 450 Pa beneath the casement

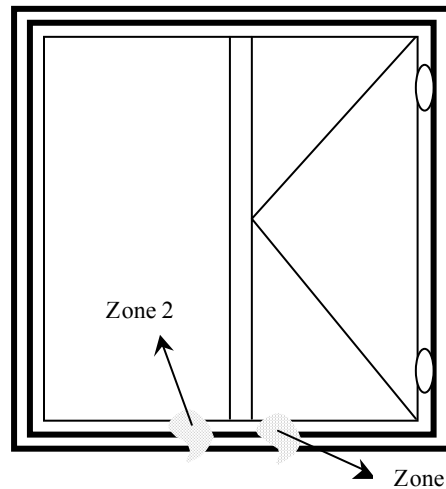


Fig. 3: The zones where leakages were observed in the water tightness test of the window samples from European larch

window (Fig. 4; zone 1). Turning into flow occurred at 600 Pa at this part. Taking these values into considerations, these rates are much better than the previous wooden windows, so we can say that quality of production, workmanship and fitting was rather high. After test examination told us the leakage on the casement window stemmed from the drainage channels. Because, there were some openings where the channels had contact with mullion profile and hinges side of the window, which affected the resistance to water leakage in a negative way. And leakages from glazing bead may have happened because the bead was not tightly enough jointed with window sash and the uniform thickness

Table 15: In the withstand wind loads of windows out of European larch, results of air permeability test after P2 pressure

Pressure (Pa)	Per scope (m <sup>2</sup> )			To the seal length (m)		
	Air loss m <sup>3</sup> /h	Widow class	Difference to the 1 <sup>st</sup> test	Air loss m <sup>3</sup> /h	Widow classes	Difference to the 1 <sup>st</sup> test
50	3.92	A3	0.018	1.15	A3	0.004
100	6.38	A3	0.291	1.85	A3	0.056
150	8.24	A3	0.442	2.39	A3	0.098
200	9.76	A3	0.564	2.82	A3	0.121
250	11.20	A3	0.768	3.21	A3	0.142
300	12.20	A3	0.773	3.52	A3	0.164
450	15.38	A3	0.942	4.48	A3	0.231
600	17.57	A3	1.024	5.09	A3	0.223
-50	4.64	A3	0.481	1.29	A3	0.073
-100	6.83	A3	0.506	1.96	A3	0.096
-150	8.61	A3	0.613	2.47	A3	0.124
-200	10.09	A3	0.692	2.92	A3	0.158
-250	11.40	A3	0.786	3.31	A3	0.187
-300	12.52	A3	0.884	3.59	A3	0.169
-450	17.30	A3	0.992	4.92	A3	0.132
-600	17.88	A3	0.763	5.16	A3	0.119

Table 16: The results of withstand wind load test of Scots pine window

Pressure (Pa) (P1)	Withstand wind load (mm)		
	1 <sup>st</sup> sensor (min)	2 <sup>nd</sup> sensor (average)	3 <sup>rd</sup> sensor (max)
2000	0.2	0.6	0.3
0	0	0	0
-2000	-0.2	-0.6	-0.3
0	0	0	0

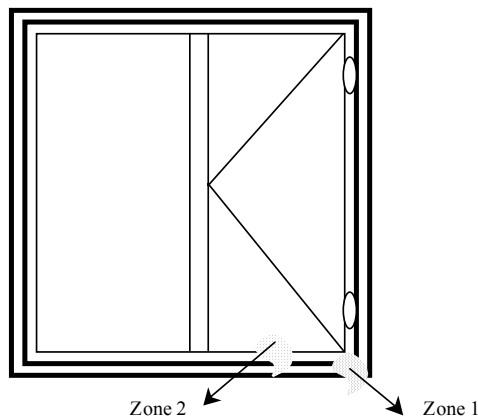


Fig. 4: The zones where leakages were observed in the water tightness test of the window samples from Scots pine

was not formed. Water tightness class of the Scots pine sample is RA7.

To make a good conclusion within this context, the leakages are mostly seen due to the failure in weatherseals and glazing beads mounting. In some windows, insufficient drainage and mounting defects of

drainage as a separate apparatus affected the water tightness class of windows in a negative way.

**Wind resistance:** In this tests, a simulated strong wind pressure, as if it came from outside, was created and the changes on mullion profile from this pressure was measured. Its results are given in Table 12 and 17. During the Sapele sample test, the water drainage pipe on the testing device floor was open, so this test wasn't applied to that sample.

Wind resistance test brings forward the importance of elasticity modulus of the materials being tested. As the resistance classes above are examined, we can see that the highest point is on PVC followed by Scots pine and European larch. One of the remarkable finding is that bending rate of PVC is seven times as much higher as the Scots pine and twelve times than the European larch. This may have happened because of the elasticity modulus of the materials. Also, why PVC had the highest value although it had a low elasticity modulus can be reasoned by the reinforcement steel for window frame. That Scots pine has  $1,17.10^5$  kp/cm<sup>2</sup> elasticity modulus whereas PVC has  $0,026.10^5$  kp/cm<sup>2</sup> shows PVC is prone to be deformed with smaller loads compared to the wood materials.

When we look at it from a different point of view, according to an air permeability test after the wind resistance test, air loss that was higher than the first air permeability test doesn't affect the air permeability class of the window. As window classes from air permeability test after a wind resistance test were the same as the ones from first test, we can see that material type is unimportant in this situation.



Table 17: In the withstand wind loads of windows out of Scots pine, results of air permeability test after P2 pressure

Pressure (Pa)	Per scope (m <sup>2</sup> )			To the seal length (m)		
	Air loss m <sup>3</sup> /h	Widow class	Difference to the 1 <sup>st</sup> test	Air loss m <sup>3</sup> /h	Widow classes	Difference to the 1 <sup>st</sup> test
50	1.80	A4	0.376	0.35	A4	0.073
100	2.53	A4	0.342	0.49	A4	0.066
150	3.06	A4	0.588	0.59	A4	0.114
200	3.55	A4	0.833	0.68	A4	0.161
250	3.92	A4	0.994	0.76	A4	0.192
300	4.37	A4	1.161	0.84	A4	0.224
450	5.60	A4	1.664	1.08	A4	0.321
600	6.68	A4	1.868	1.29	A4	0.361
-50	2.09	A3	0.127	0.40	A4	0.025
-100	2.75	A4	0.195	0.53	A4	0.038
-150	3.36	A4	0.259	0.65	A4	0.050
-200	3.86	A4	0.267	0.74	A4	0.052
-250	4.40	A4	0.310	0.85	A4	0.060
-300	5.00	A4	0.439	0.97	A4	0.085
-450	6.89	A4	0.540	1.33	A4	0.104
-600	8.65	A4	0.096	1.67	A4	0.019

### CONCLUSION

As a result, in an industrially manufactured wood window, that the quality and performance classes of the tested trees were all in lower classification than PVC has emphasized that how important isolation is but not the tree species in windows. Therefore, the isolation problem of windows must be solved giving importance to quality control in every step of the production, from the quality of workmanship in production to mounting. As a result, the following points should be taken into consideration so as to improve first the quality and performance properties and to find solutions to the problems within this context;

Firstly mounting of the accessories (hinge, fittings, water drainage system, seal system etc.) to be used in wooden windows should be emphasized. After the accessories mounted on to the windows, their adjustments (such as hinge and fittings adjustments, weatherseals used for isolation are tightly fit in the channel) should be checked and any window at least with one casement should go through a quality test. In addition to this, it should be checked that whether the glass beads are properly fit and those glazing beads should be produced with uniform thickness. Whether water drainage is efficient or not should be tested. If an aluminum channel is to be used, its isolation at zones where it has contacts with the frame should be proper and efficient.

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