

Shear strength of glue joints of PVAC adhesives and selected wood species

EWA SUDOŁ. PAWEŁ SULIK

Department of Structures and Building Elements, Building Research Institute – ITB

Abstract: *Shear strength of glue joints of PVAC adhesives and selected wood species.* The article presents the test results of glue joints made of two components (catalyzed with polyisocyanate and $Al(NO_3)_3$) PVAC adhesives and selected wood species: sapeli, sipo, eucalyptus and white meranti, in the conditions water and thermal resistance tests.

Keywords: glue joint, PVAC adhesive, laminated wood, exotic wood species, window, adhesion

INTRODUCTION

Wooden windows, some say, have been enjoying a revival recently. This renewed interest, however, entails higher expectations and requirements. Buyers expect that the windows will have not only good functional and operational properties, high thermal and sound insulation and strength but also unique esthetic value. To meet those requirements, wooden window manufacturers apply non-standard solutions, including new materials. Apart from windows made of locally growing trees – pine or oak – they also offer windows made of exotic wood. So far, only products made of Asian wood *red meranti*, a mahogany-colored wood with interesting surface texture, have been manufactured on an industrial scale.

The addition of exotic wood windows to the offer is also justified by the fact that this type of wood has been successfully used in building industry for years, e.g. for wood flooring and floorboards, stairs or internal doors. It must be noted, however, that all of the above are indoor elements. Wood for the manufacture of windows – elements directly exposed to the effects of weather – calls for special consideration.

Structural elements of modern windows, given the possibility to use different range of wood and improvement of dimensional stability, are made of glued laminated wood. Introduction of new wood species requires a detailed analysis of the gluability. Non-European wood species contain a lot of side components like resins, essential oils, waxes, fats, tannins, protein substances etc., whose varied and complex chemical composition adversely affects the gluing process. Those components usually hinder wettability of the glued surfaces or inhibit solidification of adhesives (Proszyk i Przybylak 1986). Interferences of the gluing processes, caused by the presence of side components, have been thoroughly described in the relevant literature on poly-condensation adhesives – UF, PF, MUF (Hwang G., Tang J. Noguchi M. 1993). However, the scant literature on the gluability of exotic wood with PVAC adhesives commonly used in window manufacturing indicates that the strength and resistance of the glue joints is varied and contingent on the wood species and type of adhesive (Krystofiak, Proszyk i Dobrowolski 1997, Sudoł 2007). Some research has shown that glue joints have low resistance to temperature and humidity in the context of using glued laminated elements in windows (Sudoł 2007).

EXPERIMENT

The following wood species have been selected (based on an extensive consultations with manufactures) for the study of glue joints – names and codes according to the PN-EN 13556:

- African Mahogany Sapeli (*Entandrophragma cylindricum* Sprague), code ENCY,
- African Mahogany Sipo (*Entandrophragma utile* Sprague), code ENUT,
- Eucalyptus (*Eucalyptus grandis*), not included in PN-EN 13556,
- White Meranti (*Shorea* spp. section *Anthoshorea*), code SHWM.

The wood of all species was of J2 quality class as indicated in the PN-EN 942:2008; had humidity of 9÷13% and a mean density of 710 kg/m³ (sapeli), 740 kg/m³ (sipo), 540 kg/m³ (eucalyptus), 395 kg/m³ (white meranti).

Out of the range of adhesives for window joinery, new generation PVAC adhesives were selected:

- two-component PVAC glue with 5% addition of hardener Al(NO₃)₃ (2K PVAC+Al(NO₃)₃),
- two-component PVAC glue with 15% addition of polyisocyanate hardener (2K PVAC+EPI),

Basic properties of adhesives components are shown in Table 1, based on the manufacturer's data sheets.

Table 1. Properties of adhesives components used in the study

Property, unit	Type of adhesive			
	2K PVAC+Al(NO ₃) ₃		2K PVAC+EPI	
	Type of component			
	dispersion PVAC	hardener Al(NO ₃) ₃	dispersion PVAC	hardener EPI
Density, g/cm ³	1,06	1,25	1,5	1,25
Brookfield viscosity, mPas	9000	No data	11 000	300
Solid kontent, %	51	62	60	–
NCO content, %	–	–	–	31
pH	5	1	7	No data

All adhesives were classified as corresponding to the durability class D4 according to the PN-EN 204:2002 and resistant to temp. of 80°C in the study according to the PN-EN 14257:2007.

Preparation of laminated elements (semi-finished products) was done in industrial conditions. Wood in the form of lamellae 86 x 20 mm in cross-section and 1000÷1200 mm in length underwent planning. Immediately afterwards, the gluing process was conducted using technology applied in the everyday manufacturing practice, including guidelines of the producer of the adhesive. Basic parameters of gluing are shown in Table 2.

Table 2. Basic gluing parameters

Parameter, unit	Value
Application method	roller, one-sided
Amount of application, g/m ²	165
Pressing pressure, MPa	0,6
Pressing time, min.	75

From the laminated elements thus manufactured, samples for study were obtained as indicated in guidelines of the PN-B-03156:1997.

The study included the determination of strength and resistance of glue joints according to the PN-B-03156:1997. Shear strength in compression was studied, after seasoning the samples

in conditions compliant with ITB guidelines included in the UA GS III.11/2003 concerning the required properties of semi-finished products of glued laminated wood, used for production of outdoor construction joinery. They constituted, during the window approval procedures, the basis for evaluation of the usefulness of gluelam elements. Those conditions, along with relevant requirements, are presented in Table 3.

Table 3. Requirements for shear strength of glued joints in pine-made elements, used for window production, according to UA GS III.11/2003

Seasoning conditions	Shear strength, MPa
7 days in normal climate	≥ 9,0
7 days in normal climate and 4 days in water of T 20±2°C	≥ 3,2
7 days in normal climate and 3h in T 80±2°C	≥ 5,0

RESULTS

Diagrams 1–3 show the obtained results (mean values).

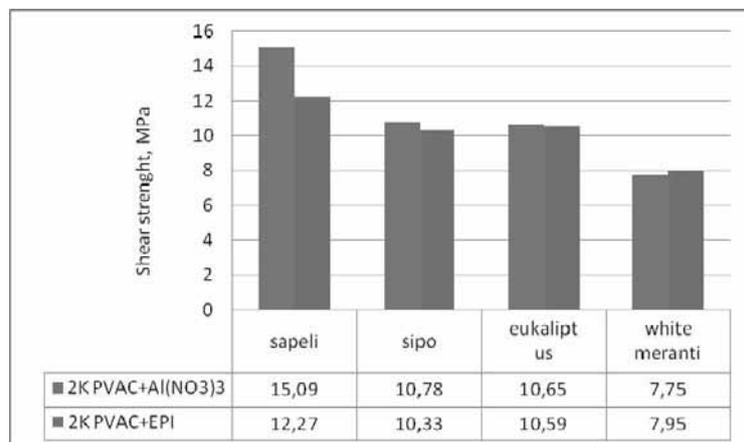


Diagram 1. Shear strength of glue joints after seasoning in a normal climate.

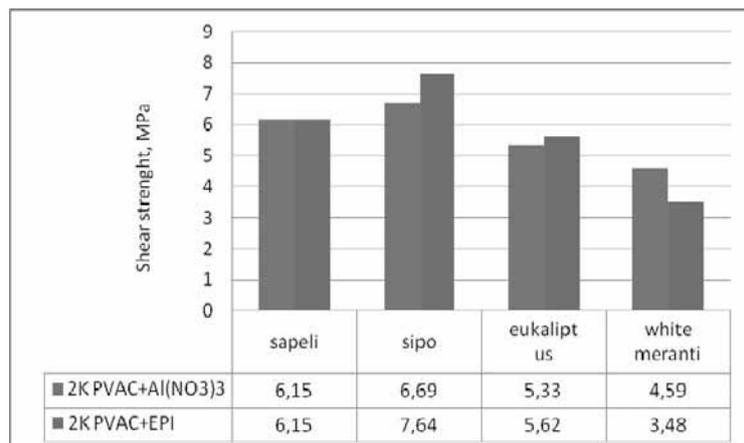


Diagram 2. Shear strength of glue joints after seasoning in a normal climate and 4 days in water of temp. 20±2°C

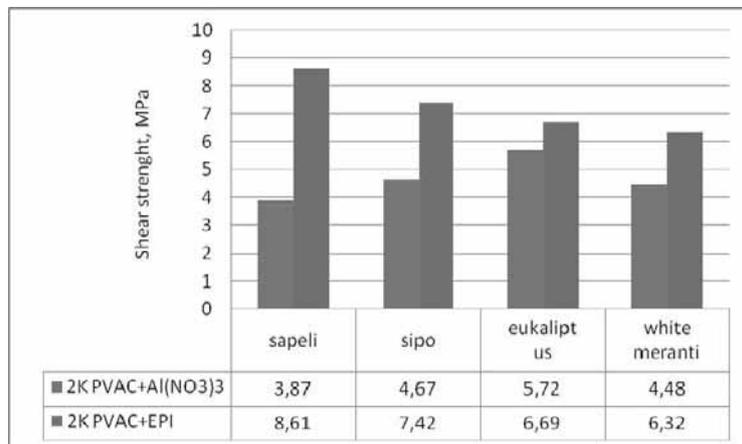


Diagram 3. Shear strength of glue joints after seasoning in a normal climate and 3h in temp. $80\pm 2^{\circ}\text{C}$

CONCLUSIONS

Results analysis confirms the strong dependency of the joint strength on the wood species. Glue joints, made with the same adhesive, in the same technological regime, of elements of different wood species, show different resistance to water and high temperature.

It must also be noted that, based on the conditions listed in Table 3, only glue joints with PVAC adhesive with polyisocyanate hardener (excluding elements made of white meranti) and joints in eucalyptus-made elements, made with the use of PVAC adhesive with $\text{Al}(\text{NO}_3)_3$ hardener can be considered as appropriate for window joinery.

The above statement should be treated as a tentative conclusion. The final evaluation of the solutions will include the results of other studies on glued joints (conducted according to the guidelines FprCEN/TS 13307-2:2009 *Timber blanks and semi-finished profiles for non-structural uses. Part 2: Production control.*

The results presented here are part of the research on the usefulness of selected exotic wood species for production of windows, conducted within the development project NR04 001 06.

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5. GS III.11/2003 dotyczące wymaganych właściwości półfabrykatów z drewna iglastego klejonego warstwowo, stosowanych do produkcji stolarki budowlanej zewnętrznej, opracowanie wewnętrzne Instytutu Techniki Budowlanej w Warszawie.

Streszczenie: *Wytrzymałość na ścinanie połączeń klejowych z klejów PVAC i wybranych gatunków drewna egzotycznego. W pracy zaprezentowano wyniki badań nad wytrzymałością i odpornością połączeń klejowych z 2K klejów PVAC – z utwardzaczem izocyjanianowym i utwardzaczem na bazie $Al(NO_3)_3$ – i wybranych gatunków drewna egzotycznego: sapeli, sipo, eukaliptus i white meranti. Określono wytrzymałość połączeń klejowych na ścinanie po oddziaływaniach charakterystycznych dla elementów przeznaczonych do produkcji okien.*

Corresponding authors:

Ewa Sudol
Paweł Sulik

Building Research Institute
Department of Structures and Building Elements
02-656 Warszawa, ul. Ksawerów 21
e-mail: e.sudol@itb.pl
p.sulik@itb.pl