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A LABORATORY COMPARATIVE STUDY ON THE PERFORMANCE AND REVERSIBILITY OF SOME TRADITIONAL AND MODERN ADHESIVES FOR FURNITURE RESTORATION

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Abstract:
The paper refers to a comparative laboratory study of some traditional natural adhesives and a modern synthetic adhesive, related to their potential use in furniture restoration for solid wood gluing and veneering. Two types of collagen based adhesives (bone glue and rabbit skin glue) and a commercial PVAc D2 type adhesive were tested to determine their adhesion capacity (gluing strength) and controlled reversibility, as a specific requirement in the conservation field. Beech (Fagus sylvatica) solid wood lamellas were used to obtain standard test samples for determining the shear strength (τ_f, MPa) of the glued joints. Poplar (Populus tremula) wood samples were veneered on both faces with aesthetic veneers of various wood species important for historic furniture. The potential controlled reversibility of these adhesives was evaluated by three original tests on adhesive films, bonded solid wood and veneered samples. The experimental results showed that the collagen adhesives provide strong (τ_f values around 13.4MPa) but fully reversible bonds, the bone glue being though easier to reverse under the action of heat and humidity than rabbit glue. For the PVAc adhesive type Novobond D2 employed in this research was determined shear strength of about 16 MPa, but its reversibility was limited. Accordingly, the employment of the commercial PVAc type adhesives in the field of furniture/wood conservation should be avoided or at least limited to very carefully considered special situations.

Key words: *collagen adhesives; PVAc adhesive; furniture/wood restoration; shear strength; reversibility.*

INTRODUCTION

The importance of conservation of wooden cultural heritage in whole its diversity from old wooden churches and houses to furniture and interior design elements, alongside household traditional objects and diverse religious items, is well acknowledged in Romania and worldwide. Compliance to the technical principles and the code of ethics, as well as a comprehensive documentation and a scientific approach are specific requirements for this complex and interdisciplinary activity (Unger *et al.* 2001, Sandu 2008, Horie 2010). Preventive and active preservation and actual restoration are the main important aspects of conservation.

Any conservation – restoration action should be based on previous scientific investigation of the object, act in the spirit of authenticity principle and employ adequate materials. Strength and stability ensuring durability of the intervention, reversibility and compatibility with the substrate are the main characteristics generally imposed to the materials for conservation (Baglioni *et al.* 2009, Horie 2010).

Adhesives are among the most important materials for wood/furniture restoration (Young 2002, Thornton 2005). The adhesives employed should primarily ensure sufficient strength of the bond, stability in time and controlled reversibility, while ageing resistance and sensitivity to the variations of RH and temperature are also important characteristics (Buck 1990, Young *et al*. 2002, Horie 2010, Monaghan 2010).

The strength of a glued joint should be comparable but not stronger than wood surrounding the joint, so that there is a low risk of causing failure within the original object, while the elastic modulus should be high enough so that the adhesive is loaded below its yield stress and at the same time sufficiently flexible to allow wooden panels to respond to the environment without a build-up of stress around the joint. Moreover, the adhesive should fail in a ductile manner and be resistant to rapid crack growth. As far as the liquid adhesive is concerned, this should have a good ability to wet the wooden surface and possess good handling and curing characteristics, in particular, an adequate working time, without an unduly long curing time (Young *et al.* 2002, Thornton 2005).

A reversible adhesive should primarily enable the parts of a joint/object to be separated without damage, ideally by cohesive or adhesive failure of the bond, under the controlled action of solvents or temperature. Therefore thermoplastics are usually employed, though recent developments made possible utilisation of cross-linkable adhesives (e.g. epoxy) in a two stage process where a permanently reversible primer (e.g. Paraloid B72) is used as a first sealing coat of the adherent (Horie 2010). At a higher level and for special applications, reversibility should consider also the possibility of (total) removal of the material from the interfaces, interference with further treatments or investigation methods (Thornton 2005, Horie 2010).

Most often natural traditional adhesives, such as collagen and casein based glues, are employed in restoration. This is in accordance to both the authenticity and the reversibility principles. The choice of adhesive should consider the identification of the original adhesive. For furniture and other wooden artefacts, collagen based adhesives were generally used (Young *et al.* 2002, Thornton 2005).

The main sorts of collagen based adhesives, also known as animal glues are bone glue (Scotch glue), hide (skin) glue, rabbit glue (rabbit skin glue) and fish glue. Bone glue and hide glue are typically employed for solid wood gluing and veneering, while rabbit glue is commonly used for the preparation of wooden substrate for gilding and fish glue is mostly used for the conservation of polychrome wood (Thornton 2005).

Animal hide and bone glues have been used for centuries in the construction of many wooden objects. Very old wooden objects (e.g. wood panel paintings of five hundred years) with intact joints are a proof of their durability and long-established performance in certain limits, representing also the main reasons for their preferential employment in restoration. Another reason is that they remain reasonably reversible, unlike most of the synthetic products. Their main drawbacks are: their susceptibility to biological attack, alteration of their mechanical and adhesive properties according to fluctuations in humidity and the uncomfortably short working times (Young *et al.* 2002, Thornton 2005). The later is related to their usual employment as hot glue solutions that have to be applied on the substrate very quickly to avoid viscosity increase up to gelling prior pressing (usually minimum 8h at room temperature). Gel depressants (e.g. urea, oxalic acid) and/or preservatives (e.g. salicylic acid) may be added to extend the working time and improve biological resistance.

Film formation is a physical process of gelling followed by water loss. Therefore, it can be reversed by the action of water, heat or wet heat (steam). Ethyl alcohol can be also employed and acts by adhesive film dehydration leading to cracking (Thornton 2005). However, the reversibility of collagen adhesives can be somehow affected in time by ageing and possible cross-linking with different additives (AIC-BPG 1989, Buck 1990).

PVAc water dispersion adhesives are ones of the few modern synthetic adhesives which penetrated in the conservation-restoration field. They were first proposed for the structural conservation of museum objects in the early 1950s and a variety of these commercially prepared adhesives (e.g. Resin W, CM Bond CM1-CM4, Elvace 40704) have since been used for paper and wood conservation as consolidants or adhesives. These adhesives are easy to employ as do no need any preparation, are applied and pressed at room temperature and form strong and still flexible bonds to many porous materials (AIC-BPG 1989, Young 2002).

Their thermoplastic character and the physical mechanism of film formation consisting in water elimination and coalescence of particles, valid for the classical non-cross-linkable sorts, should ensure, at least theoretically, their reversibility under the action of water and temperature (AIC-BPG 1989, Timar 2006). However, their effective reversibility in conservation applications is still a subject imposing discussion. The dry film can be only swollen in water not dissolved, while their solubility in organic solvents is limited. These facts correlated with their difficult mechanical removing, especially from porous and absorbing substrates or tight joints are reasons to consider them as practically irreversible (Young 2002, Thornton 2005, http://www.aboutrestoration.eu/text/adhesives.pdf).

Moreover, PVAc water dispersion adhesives do usually contain external plasticizers and this is not advisable for conservation materials. This is because ageing of the externally plasticized materials is usually associated with plasticizers migration and loss, leading to embrittlement, colour changes, staining of adherents and reduced solubility / reversibility (AIC-BPG 1989, Young *et al.* 2002, Horie 2010). The acidic pH of some technical sorts and the possibility of acetic acid formation by thermal degradation are other points of concern. Moreover, modern commercial PVAc water dispersion adhesives have generally an unknown complex composition, are based on various copolymers and contain different additives (plasticizers, solvents, thickeners, compounding materials, or even cross-linkers) to make them competitive on the market of adhesives for new wooden products with improved performance in different climatic conditions (D1-D4) (AIC-BPG 1989, Timar 2006). All these additives interfere with the potential reversibility of these adhesives. This is further negatively influenced by ageing, the potential cross-linking reactions occurring in time and the migration and loss of external plasticizers.

Despite of the importance of reversibility as a property generally imposed to conservation materials, adhesives included, there is no standard test for its evaluation and the literature information is rather based on practical experience of materials utilisation than on specific tests. Research data on this subject is limited. Monaghan (2010) studied the effects of concentration and artificial ageing on the strength (resistance to peeling) and reversibility of a wallpaper adhesive for conservation use and proposed a manual qualitative test for assessing mechanical reversibility of gluing, alongside a percentage rating scheme. Other researchers employed different self -designed laboratory solubility tests to assess the potential reversibility of materials / adhesives for conservation use (Blackshow and Ward 1982, http://www.aboutrestoration.eu/text/adhesives.pdf). The need for more research and standardisation in this field is obvious.

Within the present research a PVAc modern adhesive was compared with two types of collagen based traditional adhesives in terms of bond strength and potential reversibility under the influence of water and temperature in controlled conditions. For this purpose solid wood glued samples and veneered samples were prepared and tested. Original laboratory tests were proposed for assessing the reversibility of the tested adhesives.

MATERIALS AND METHODS

Two types of traditional, collagen based adhesives (coded A1 and A2) and a sort of modern water dispersion PVAc adhesive type D2 (coded A3) were employed. The collagen adhesives were prepared for application as hot glue solutions, while the PVAc dispersion was used without any preparation. Oxalic acid (gel depressant) or salicylic acid (preservative) were used as additives for the collagen adhesives, so that two types of bone glue solutions (A1.1, A1.2) and one type of rabbit skin glue adhesive solution (A2.1) were prepared. Data referring to the actual sorts of employed adhesives, the composition of the prepared solutions, their solids content, viscosity at the application temperature (expressed as flow time through a STAS cup with a nozzle of 8mm diameter) and pH are presented in Table 1.

Adhesive films were prepared by applying the adhesive solutions as thin layers on microscope lamellas and allowing them to dry at room temperature. After total drying and conditioning (about 14 days) the films were examined under a microscope and then carefully detached from the support and placed in sealed plastic bags.

The adhesives were compared in terms of adhesion properties by determining the standard shear strength of glued joints according to SR EN 205. For this purpose beech wood lamellas (150×80×5mm) were glued together and further mechanically processed to obtain the testing samples. The gluing parameters were: application rate (Csp) 200g/m^2, specific pressure 0.6MPa, pressing temperature 20°C, pressing time 4h. All the glued samples were then maintained in press without pressure overnight and further conditioned in the laboratory for at least 7 days prior processing and testing. For the actual test a universal testing machine FMPW 1000 was employed, the test samples being supposed to tension until breaking. The shear strength (τ_f, MPa) was calculated by reporting the fracture load (Fr) to the surface of the glued area actually tested. The type of failure was also observed. After testing the samples were used in a reversibility test.

Table 1

Adhesives employed in the experimental study – types, preparation and characteristics

Adhesive type	Commercial sort / Producesr Aspect	Preparation for application	Solids content [%] (as applied)	Tsc Φ 8mm [s]	pH	Code
Bone glue (Scotch glue)	Product of SC Ajexim SRL-Rm.Valcea / granules, opaque, yellowish	75 g adhesive 125 ml water 0.75 g salicylic acid	36.06	13.8 (60°C)	5.5	**A1.1**
		50 g adhesive 83.5 ml water 2.75 g oxalic acid	36.35	12.9 (60°C)	4	**A1.2**
Rabbit skin glue	DEFFNER&JOHANN Granules, transparent, yellowish	50 g adhesive 100 ml water 0.5 g salicylic acid	35.61	15.7 (60°C)	5.5	**A2.1**
PVAc dispersion	NOVOBOND D2/ Viscous white liquid	None	53.26	200 (20°C)	6	**A3**

The same adhesives were employed for surface veneering of poplar wood samples (100×50×10mm) on their faces with veneers of walnut (*Juglans regia*), cherry wood (*Prunus avium*), oak (*Quercus robur*) and beech (*Fagus sylvatica*). The gluing parameters were the same, excepting the application rate which was 120g/m^2. Each of these samples was longitudinally cut into 3 samples used in another reversibility test.

In order to assess and compare the reversibility of the employed adhesives self-designed tests were carried out. Firstly, the resistance to water at 20°C and 80°C of the dry adhesive films was assessed. For this purpose, two series of small samples of dry adhesive films (around 10×10mm, approximate weight 0.200g) were placed in Petri dishes and 25ml distilled water was added. One series was maintained and inspected periodically at room temperature for a total period of time of 96h (4 days) and then placed in an oven at 80°C for 60min. The second series of samples was kept at 20°C for 60min and then placed in the oven at 80°C for another 60min. The samples were inspected at different intervals of time during the test and at the end of the test to observe any changes in aspect, shape, softness and swelling up to disintegration or dissolution (Fig.1a).

For the glued samples several methods employing as reversing agents heat and water were imagined and tried. Finally the following two methods, one for solid wood assemblies and one for veneered samples, were considered as appropriate. The glued solid wood samples (the 2 parts resulting from the shear strength test) were placed in a glass jar and distilled water was added. The samples were kept immerged in water for 1h at room temperature. Then one sample was removed from water and put in a sealing plastic bag. Both samples (one submerged in water and one in the plastic bag) were then introduced into a laboratory oven pre-heated at 80°C and maintained for another hour. After this period they were removed from the oven and inspected to see if free detachment has occurred or not. A forced detachment of the resistant samples was tried and their behaviour described (Fig. 1b).

a b c

Fig. 1

Methodological aspects concerning reversibility testing on: a – adhesive films; b- solid wood glued samples; c-veneered samples.

For the veneered samples the method was slightly different. The samples were brushed with distilled water on both faces until saturation and placed individually in sealing plastic bags. These were introduced into a laboratory oven pre-heated at 80°C for 20min. After this interval each of them was removed from the bag and examined to see if detachment of veneer occurred or not, and the percentage area of detached veneer as result of adhesive reversibility under high temperature and moisture conditions was approximated. Then the procedure was repeated and the samples were re-examined after 40min. If detachment was not complete, the same procedure was repeated for the third time. After this period (total 60min) a forced

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detachment of veneer was tried and pictures were taken (Fig.1c). For the samples glued with the PVAc adhesive (A3) another test continuing from 60 to 120 minutes was carried out.

RESULTS AND DISCUSSIONS

Application and film properties

The prepared adhesive solutions based on bone glue and rabbit skin glue (A1.1, A1.2, A2.1) had a pretty constant solids content of about 36%. They were homogeneous and sufficiently fluid at 60° (Flow time through STAS viscosity cup, Φ 8mm, Tsc between 12.9 and 15.7s) to allow their uniform application on the wooden substrate as hot solutions. Their working time (period of time within which the adhesive though in contact with the cold substrate still has a viscosity low enough to allow spreading and wetting) exceeded 5min, the actual time needed to prepare the 6 replicate samples for one pressing lot. It was obvious that especially the addition of oxalic acid decreased the viscosity and extended the working time, making the application of these adhesives much easier compared to similar solutions without gel depressant additives. Moreover, samples of the prepared adhesives solutions were kept in jars covered with paraffin film for more than one month in laboratory conditions and no sign of bio-degradation was detectable.

The PVAc water dispersion adhesive was used without any preparation excepting stirring. It had a higher solids content (about 53%) and a much higher viscosity (Tsc Φ 8mm at 20°C around 200s). However, application was easy and uniform. For this type of adhesives the working time is referring to a maximum assembly time from application on the adherents until effective pressing to avoid pre-curing in order to ensure adequate wetting and is long enough (20-30min) not to pose any practical problems.

The solid films resulting from the collagen adhesives (A1.1, A1.2, A2.1) were transparent, yellowish, hard and quite rigid though some flexure strain could be applied without breaking, while the PVAc film (A3) was opalescent, whitish, soft and very flexible.

Bond strength

The mean values of the standard shear strength, τ_f, [MPa], for the considered adhesives are presented comparatively in Table2. These experimental values were determined for glued joints obtained at a constant application rate (Csp = 200g/m^2) for adhesives with different solids content (Csu, %), thus for resulting adhesive films of different thickness. That is why these values were used as basis to theoretically calculate (Equation 1) some normalized values for a similar film thickness corresponding to a constant application rate of 100g/m^2 as solids content, $\tau_{f\text{-}100}$, [MPa].

$$\tau_{f-100} = \frac{100 \cdot 100 \cdot \tau_f}{Csp \cdot Csu} \quad \text{[MPa]} \qquad (1)$$

where:

$\tau_{f\text{-}100}$ – normalized shear strength of the joint, theoretically calculated for an application rate of 100g/m^2 as solids content, in MPa

τ_f – standard shear strength, in MPa

Csp – real application rate, in g/m^2

Csu – solids content of the adhesive as applied, in %

Table 2

The shear strength of the studied adhesives (mean values of 6 replicates)

Adhesive code	Standard shear strength τ_f, [MPa] (Csp = 200g/m^2 – adhesive solution)		Normalised shear strength $\tau_{f\text{-}100}$, [MPa] (Csp = 100g/m^2 – solids content)	Csu [%]
	Mean value	Standard dev.	Calculated	
A1.1	13.33	1.68	18.48	36.06
A1.2	13.44	2.51	18.49	36.35
A2.1	13.54	1.22	19.01	35.61
A3	15.97	3.21	15.00	53.26

As can be observed in Table 2, the standard shear strength for the collagen adhesives tested was very similar, around 13.4MPa, and only slightly lower (with about 15%) than the value of about 16MPa determined for the PVAc adhesive Novobond D2. This is in accordance to literature data based on experimental tests of glued joints (Schofield 2007). All these values are superior to the value of min 10MPa required by SR EN

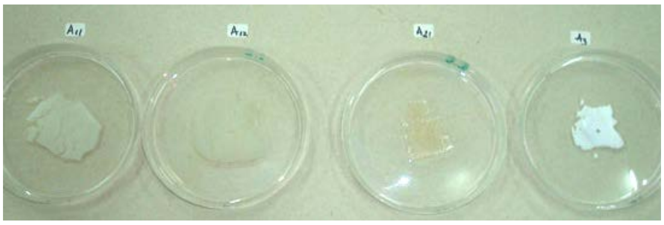
204 for non-structural adhesives (shear strength in dry state for D1 applications) and certainly more than enough for restoration purposes, where the adhesive strength should not overpass the wooden adherent strength.

Moreover, the normalized shear strength values theoretically calculated for a constant application rate as solids content of 100g/m^2 are higher for the collagen based adhesives compared to the PVAc. This clearly points out that the traditional collagen based adhesives can ensure high strength wooden glued joints.

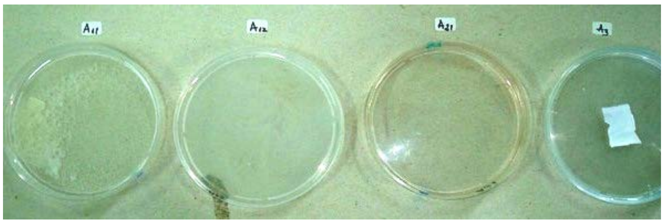
Reversibility

The potential reversibility of the studied adhesives was assessed and compared employing different self established tests on the solid adhesive film and glued wooden samples. In all these cases the reversing agents were water and heat.

The reversibility test carried out on the adhesive films clearly pointed out two aspects illustrated in Fig. 2. Firstly, it is necessary both water and heat to reverse the collagen adhesives films up to dissolution or disintegration. Thus the dry solid films absorbed relatively quickly water at room temperature and got swollen but did not dissolve or disintegrate at this temperature, irrespective of the testing time (1 h or 4 days). If heated at 80°C in water the adhesives films disintegrated (A1.1) or dissolved totally (A1.2, A2.1) forming colloidal solutions (perfectly clear for A2.1 and opalescent for A1.2). Secondly, the PVAc adhesive film got just swollen by immersing in water and did not disintegrate irrespective of the immersion time at 20°C or the cumulation of water and temperature as reversing agents. This confirms literature information (Blackshow and Ward 1982, Young 2002, Thornton 2005).



a



b

Fig.2

Pictures showing the different resistance to water and temperature of the studied adhesives films: a - samples after testing at 20°C/ 4 days; b – samples after testing 60 min/20°C followed by 60min/80°C.

The results of the reversibility test carried out on the beech solid wood glued samples are summarized in Table 3 and illustrated by the pictures in Fig. 3a.

Table 3

Results of reversibility test on solid wood glued samples

Adhesive code	**Solid wood adherents**	**Reversibility – Oven method 80°C/60 min**	
		Sealed plastic bag	**Immersed in water**
A1.1	Beech / Beech	Free total detachment Sticky interfaces	Free total detachment
A1.2	Beech / Beech	Free total detachment Sticky interfaces	Free total detachment
A2.1	Beech / Beech	Free total detachment Sticky interfaces	Free total detachment
A3	Beech / Beech	Whitening of adhesive No free detachment Forced detachment is not possible	Forced total detachment – difficult

This data clearly show that all the collagen based adhesive solutions used were easy to reverse, whilst the PVAc adhesive tested behaved actually as a non-reversible adhesive, confirming observations from the previous test on adhesives films and literature data (Thornton 2005, http://www.aboutrestoration.eu/text/adhesives.pdf).

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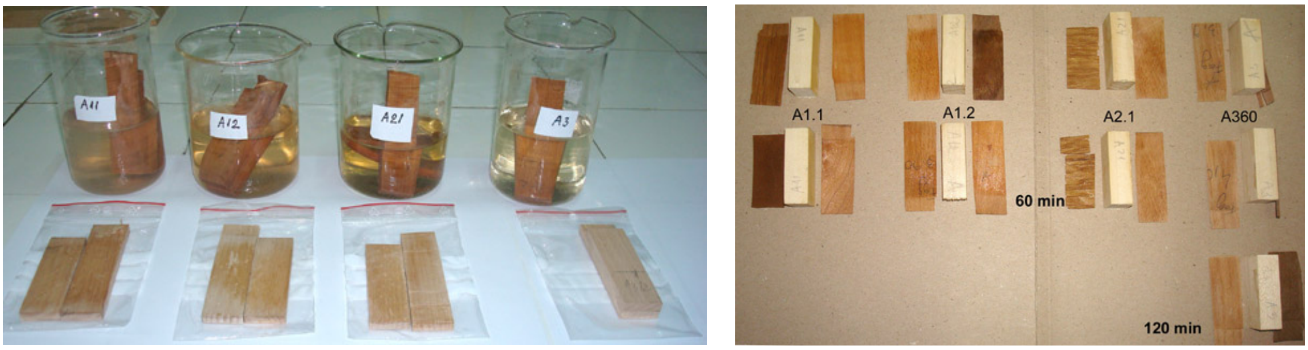
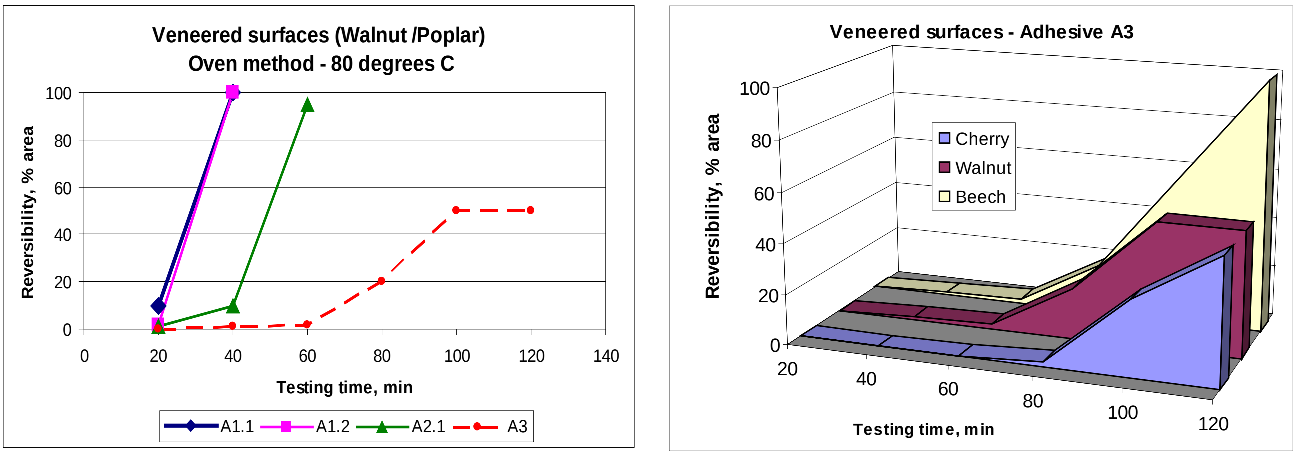


a b

Fig. 3
Images illustrating the different reversibility of the studied adhesives: a - tests on solid wood glued samples; b - tests on veneered samples.

The results of the reversibility test carried out on veneered samples of poplar solid wood laminated on the both faces with veneers of different wood species are summarized in Table 4 and illustrated by the pictures in Fig. 3b and the graphs in Fig. 4.



a b

Fig. 4
The different degree of reversibility of the studied adhesives as revealed by a test on veneered samples (a) and the influence of wood species (b).

All this data prove that collagen adhesives are totally reversible under the combined action of water and heat. However, some differences could be noted between bone glue (A1.1, A1.2) and rabbit skin glue (A2.1), the former being easier to reverse (total free detachment of veneers in 40min) than the last one (total detachment of veneers only after 60min). This is partially in contradiction to the previously presented data resulting from tests on adhesive films indicating A2.1 more reversible than A1.1. Compared to the collagen adhesives, the PVAc adhesive used in this research was very difficult to reverse. Almost no free detachment occurred after 60 minutes and even mechanically forced detachment with a flexible spatula was insignificant or led to veneer breaking in some cases. A further extended test allowed partial forced mechanical detachment of veneers after 120min (Fig. 4a, b).

Another aspect revealed by this test is related to the different adhesion capacity of different wood species, which may bring about some differences in practical reversibility. These differences were easier to observe for the least reversible adhesive (A3 - see Fig. 4b) than for the more reversible ones (A1.1, A1.2, A2.1) where different percentage of surface reversed as a function of wood species could be observed only after 20min of testing (see Table 4).

Table 4

Results of the reversibility test on veneered samples of poplar (different veneers)

Adhesive type	Sample	Veneers (2 faces)	Reversibility test – Oven method, 80°C Time of testing		
			20 min	**40 min**	**60 min**
A1.1	**1**	- oak	- free detachment of a 10mm strip on the length of the sample (40-50%)	- total free detachment (100%)	-
		- cherry	- free detachment of a 3 mm strip on the whole length of the sample (~15%)	- total free detachment (100%)	-
	2	- cherry	- free detachment of a 5mm strip on the whole length of the sample (~25%)	- total free detachment (100%)	-
		- walnut	- free detachment on limited area on opposite corners (‹10%)	- total free detachment (100%)	-
A1.2	**1**	- beech	- free detachment on limited area on opposite corners (~5%)	- total free detachment (100%)	-
		- walnut	- very limited detachment at one corner	- total free detachment (100%)	-
	2	- beech	- very limited detachment at one corner	- total free detachment (100%)	-
		- cherry	- free detachment of a 4mm strip on the whole length of the sample (~15%)	- total free detachment (100%)	-
A2.1	1	- walnut	- very limited detachment at one corner	- detachment on limited area (10%)	forced easy detachment (95%) sticky surface-
		-oak	- very limited free detachment at one end, of ~ 1 mm	- free detachment from the sample ends (~30%)	- forced total detachment - easy (100%)*
	2	- beech	- free detachment of a 5mm strip on the whole length of the sample (~25%)	- total free detachment (100%)	-
		-oak	- limited free detachment at one end, of ~1-2 mm	- free detachment from the sample ends (~30%)	- forced total detachment – easy (100%)*
A3	1	- beech	- insignificant limited detachment at one corner	- very limited detachment at one corner, ~0.5 cm^2	- similar as after 40min
		- cherry	- no sign of detachment	- no sign of detachment	- no sign of detachment
	2	- beech	- very slight detachment at one corner, ~5 mm^2	- similar as after 20 min	- limited detachment on a area of ~ 1cm^2
		- walnut	- no sign of detachment	- very limited detachment at one corner, ~2-3 mm	- limited detachment at one corner ~5 mm
Adhesive		**Veneers**	**80 min**	**100 min**	**120 min**
A3	**1**	- beech	- detachment of a 5mm strip on the whole length of the sample (~20-25%)	- forced partial detachment (~70 %)*	- forced total detachment (100%)*
		- cherry	- detachment on a limited area at one corner, ~ 1 cm^2	- forced partial detachment (~30 %)*	- forced partial detachment (~50%)*
	2	- beech	- detachment from one corner (~20%)	- forced partial detachment (~50 %)*	- forced total detachment (100%)*
		- walnut	- forced limited detachment (~20 %)	- forced partial detachment (~50 %)*	- forced partial detachment (~50%)*

Notes: 1- values in brackets represent an approximation of the area of veneer detachment as a result of reversibility as percentage from total veneered area; **2**-* -marks and differentiates forced detachment with the aid of a flexible spatula from free detachment (no mechanical action, just the effect of water and temperature)

CONCLUSIONS

The right choice of materials is a key point in any conservation-restoration action. The materials employed should ensure reasonable strength and stability of interventions and at the same time reversibility in controlled practical feasible conditions.

With this respect, the results of this research clearly demonstrate that the collagen adhesives should remain the first option in wood/furniture restoration. They ensure strong and perfectly reversible bonds. Similar shear strength values were obtained for bone glue and rabbit skin glue, while slight differences in terms of reversibility were registered, bone glue being easier to reverse than rabbit skin glue. The salicylic acid and oxalic acid used as additives reduced the sensitivity to biodegradation of the prepared collagen adhesives solutions improving also their application properties and the actual working time.

PVAc adhesives can provide apparently stronger bonds but their reversibility is really problematic. Moreover, this property can vary between different technical sorts, with different compositions, prepared nowadays for different domains of utilisation (D1-D4). Accordingly the use of PVAc adhesives as replacing collagen adhesives should be carefully considered only for special cases. A previous testing of their properties, including both bond strength and potential reversibility, is necessary for a correct evaluation of advantages and disadvantages.

Three laboratory reversibility tests were proposed in this paper and their outcomes correlate very well with practical experience.

To finally conclude, it has to be said that the problem of a suitable adhesive for wood/furniture restoration should be examined in the complex context of a certain case and in relation to the actual service conditions and possible preventive preservation measures. A certain adhesive can not be qualified in absolute terms as good or bad, but just suitable or not suitable for a certain application.

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