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The Effect of Consolidants on the Mechanical Fracture Behaviour of Gesso-Type Foundations in Multilayered Decorative Coatings

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Abstract

Determining the efficiency and performance of polymer formulations used as consolidants for fragile, multilayered decorative coatings is often a great challenge in conservation. This paper reports the results of tests that investigated the performance of a variety of consolidants for the stabilization of such coatings. East Asian lacquer coatings were used as a typical representative of multilayered coatings with protein-bound (gesso-type) foundation layers that show brittle fracture, delamination, and flaking. Mechanical strength tests were undertaken with a fracture mechanics approach using the standardized double cantilever beam (DCB) method. The independent material property fracture energy, G_{IC} , was measured, and the fracture behaviour of the brittle, protein-bound foundation layers was determined. DCB specimens were prepared, fractured, then consolidated with a variety of polymer formulations and re-fractured to provide data for direct comparison. The tested consolidants included isinglass, hide glue, Lascaux Medium for Consolidation, Paraloid B-72 and B-48N, Mowiol 3-83, Mowilith 50, and Mowilith DMC2. Cross sections were taken from the DCB specimens before second-phase fracture to determine penetration behaviour and gap-filling ability of the consolidants. The results showed that the method could determine measurable differences in fracture energy and penetration behaviour, and could also supply valuable and detailed information on the location of crack path propagation.

Titre et Résumé

L'effet des agents de consolidation sur le comportement à la rupture mécanique de la préparation de gesso de revêtements décoratifs multicouches

Les défis rencontrés dans le domaine de la restauration reposent souvent sur la nature complexe des approches, par exemple celle consistant à déterminer l'efficacité et le comportement de formulations polymères utilisées comme agent de consolidation pour traiter des revêtements décoratifs multicouches fragilisés. Le présent article traite des résultats d'essais visant à étudier le comportement de divers agents de consolidation employés pour assurer la stabilisation de tels revêtements. Des revêtements de vernis-laque comme ceux d'objets provenant de l'Asie de l'Est ont été choisis comme matériaux représentatifs de revêtements multicouches comportant des préparations de nature protéique (du type gesso) qui présentent des zones de rupture fragile, de décollement des couches et d'écaillage. Des essais de détermination de la résistance mécanique ont été réalisés, en utilisant une approche basée sur la mécanique de la rupture et la méthode d'essai normalisée sur double éprouvette en porte-à-faux (DEP). Une propriété des matériaux indépendante, soit l'énergie de rupture G_{IC} , a été mesurée et le comportement à la rupture des couches de préparation de nature protéique fragilisées a été déterminé. Des échantillons du type DEP ont été préparés et soumis à une force suffisante pour entraîner leur rupture; ils ont ensuite été consolidés avec diverses formulations

polymères et ont subi une nouvelle rupture afin d'obtenir des données permettant une comparaison directe. Les agents de consolidation mis à l'épreuve comprenaient l'isinglass (colle de poisson), la colle de peaux, le produit Lascaux d'adhérence moyenne utilisé pour la consolidation (*Lascaux Medium for Consolidation*), le Paraloid B-72 et le Paraloid B-48N, le Mowiol 3-83, le Mowilith 50 et le Mowilith DMC2. Des sections transversales ont été découpées dans les échantillons du type DEP avant de leur faire subir une rupture lors de la deuxième étape susmentionnée, et ce, afin de déterminer le degré de pénétration des agents de consolidation et leur capacité d'obturation des vides. Les résultats indiquent que la méthode permet de déterminer des différences mesurables pour les valeurs expérimentales de l'énergie de rupture et du degré de pénétration. Elle peut aussi fournir des renseignements détaillés précieux sur l'emplacement de la voie de propagation des fissures.

Introduction

The consolidation of fragile, gesso-type foundation layers in multilayered, decorative coatings on wooden substrates is a complex task that still poses great challenges in conservation. To further improve the understanding of consolidant performance and to facilitate well informed choices on which consolidants are most suitable for the efficient stabilisation of such coatings, it is vital to extend the knowledge of the mechanical characteristics of the fragile coating. Furthermore, detailed information is required on how these characteristics change with a chosen treatment. However, these details are rarely available to conservators. Component materials of applied arts objects are generally inhomogeneous and technical data are seldom known. By the time such objects require conservation, these materials are usually aged and their properties have changed in various ways and to varying degrees. Additionally to the lack of information on the aged material, the properties of the consolidants and adhesives available are – if at all – mostly known only for bulk material, but not necessarily when dispersed in a porous substrate and potentially containing numerous voids.

To tackle this problem, this paper will report the results of research based on a new approach for the performance evaluation of polymer formulations used to consolidate fragile decorative coating structures. Based on an adaptation of the standardised double cantilever beam (DCB) method, this approach looks at the fracture properties of test specimens that can be tested twice, i.e. before and after consolidation. This facilitates direct comparison between individual specimens, and thus enables a better evaluation of the consolidants' behaviour once applied to the fragile material. For illustration purposes, this research was performed on East Asian lacquer coating structures that contain protein-bound foundation layers, as a typical example of decorative coatings most prone to delamination and flaking.

The methodology of the test method was recently presented in more detail at the ICOM-CC 16th Triennial Conference, Lisbon 2011 (Schellmann and Taylor 2011). The present paper therefore focuses on the results gained from the tests. Further details on these results are also due to be published in a Ph.D. dissertation by Schellmann (forthcoming) in 2012.

Materials and Methods

DCB test specimens

Measuring the fracture energy in mode I (i.e. in tensile loading), G_{Ic} , is a promising method to establish the resistance to fracture of multilayered coating layers. G_{Ic} is an independent material property influenced neither by the geometry of the cracked body nor by the test conditions and denotes the amount of energy required to propagate a pre-existing crack through a material. To measure G_{Ic} , a rather simple specimen is tested in tensile loading following a standardised method (BS7991 2001).

Details of the DCB specimen containing the material or joint to be tested are given in Figure 1. The substrate was cut from a seasoned log of Québec yellow pine (*Pinus strobus*). The foundation was a gesso-type mixture of animal glue and Japanese clay powder (*tonoko*), based on a 10 weight percent (wt%) solution of bovine hide glue mixed with finely ground *tonoko* to a weight ratio of 1:1. These materials were used for two types of test specimens: type A, as shown in Figure 1, contained just one coating layer (foundation only) between two wood substrates. The foundation was applied to a pair of wood boards, which were then placed together incorporating a starter foil (to serve as a crack initiator in the desired position of the layer) and two steel wires as spacers (to ensure constant and known adhesive layer thickness), and pressed until dry. Type B specimens were prepared by applying foundation in two consecutive layers to only one board of each substrate pair. After drying, the foundation was coated with five layers of East Asian lacquer including a starter foil. The second wood substrate was subsequently adhered to the top lacquer surface using epoxy resin.

DCB test specimens were cut from these sandwiched boards and ground to final dimensions of 20 mm width and 150 mm length. Specimens were equilibrated at 53.0 (± 1.5) %RH at 21.0 (± 1.5) °C for 2.5 months (type A) and 3.5 months (type B). The longer equilibration time for specimen type B was solely governed by the availability of the testing equipment.

Prior to testing, aluminium end-blocks were attached with cyanoacrylate adhesive (super glue) on the specimen end incorporating the starter foil. To enable crack length measurement, a scale with 1 mm increments was attached to one of the beams.

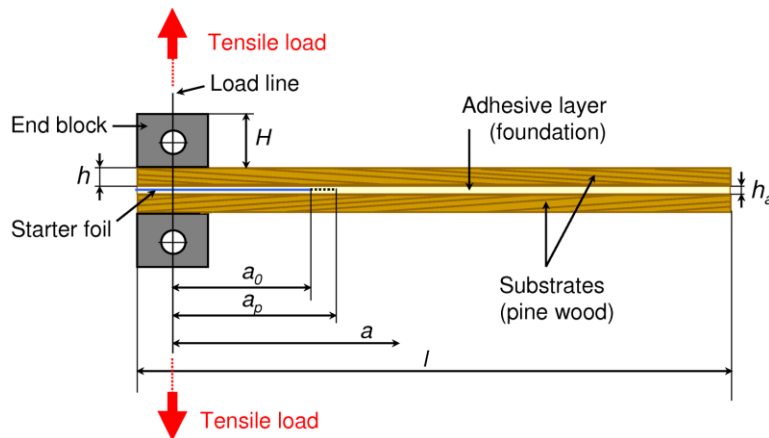


Figure 1. DCB specimen with end-blocks according to BS7991 (2001). l : total specimen length (150 mm); h : thickness of the wood substrate (4 mm); h_a : thickness of the adhesive (foundation) layer; H : thickness of the end-block (13 mm); a_0 : starter foil length from the load line (30 mm); a_p : pre-crack length, measured from the load line to the tip of the pre-crack; a : crack length, measured between the load line and the observed crack tip (> 30 mm).

Consolidation of DCB specimens

After initial fracture (cf. ‘Fracture testing’ section below), the DCB specimens were re-adhered with consolidants, to provide specimens for second-phase fracture. Ten different polymer-formulations were chosen (see Table 1), and applied with a brush to both fracture surfaces of four DCB specimens each. The paired beams were joined together and pressed during drying, before being equilibrated as described earlier.

Staining of consolidants

To facilitate visualisation of consolidant distribution within the specimens, the protein-based formulations and the acetone-dissolved acrylic were stained with Fast Green (Schramm and Hering 1988) and Solvent Blue G respectively prior to application, for subsequent examination in cross-section. Cross-section samples were cut from the ends of the DCB specimens before second-phase fracture (see Figure 2b), then polished and examined under incident visible light using an optical microscope (Zeiss AxioScope A1, reflected light geometry). The remaining consolidants were stained in cross-section, using Solvent Blue G in ethanol for acrylics, and Lugol’s solution for starch, poly(vinyl acetates) (PVAC) and poly(vinyl alcohols) (PVAL) (Lehmann 2004), as described in Table 1.

Table 1. Consolidants used for DCB specimens.

Type	Polymer	Solvent/ diluent	Concen-tration	Stain
			[wt%]	
Protein	Isinglass	water	10	Fast Green (0.1 wt%), added to consolidant
	Fish glue	water	22.5	Fast Green (0.1 wt%), added to consolidant

	Hide glue	water	10	Fast Green (0.1 wt%), added to consolidant
	Isinglass/ starch	water	13.3	Fast Green (0.1 wt%), added to consolidant / cross-section stained with Lugol's solution
Acrylics	Paraloid B72	toluene	25	Solvent Blue G, cross-section stained with 0.2 wt% in ethanol (exposure time 10 min)
	Paraloid B72	acetone	25	Solvent Blue G (0.1 wt%), added to consolidant
	Paraloid B48N	toluene/ xylene (1:1)	25	Solvent Blue G, cross-section stained with 0.2 wt% in ethanol (exposure time 10 min)
	Lascaux MfC	(aqueous dispersion) undiluted	25	Solvent Blue G, cross-section stained with 0.2 wt% in ethanol (exposure time 3-5 min)
PVAL	Mowiol 3-83	water	25	Lugol's solution (exposure time 3 seconds)
PVAC	Mowilith 50	toluene	20	Lugol's solution (exposure time 3 seconds)
	Mowilith DMC2	(aqueous dispersion) + water	10	Lugol's solution (exposure time 3 seconds)

Fracture testing

The DCB specimens were fractured under tensile loading, using an Instron 5584 universal testing machine fitted with a 5 kN load-cell and a humidity-controlled chamber. The tests were performed at a monotonic cross-head displacement rate of 0.3 mm/min and at 53.0 (± 0.5) %RH and 21 (± 1) °C. The applied load, P , displacement, δ , and crack length, a , were recorded, and G_{Ic} was calculated according to the British Standard 7991 (2001) using:

$$G_{Ic} = \frac{3P\delta}{2B(a + |\Delta|)} \cdot \frac{F}{N}$$

where B is the specimen width. Δ , N and F are specimen-specific correction factors for crack-length, end-blocks, and large displacement, as defined in the Standard. Data analysis was undertaken using a customised Microsoft Excel spreadsheet (Blackman and Kinloch 2001a and 2001b).

Results and Discussion

To establish the effect of the consolidants on the fracture behaviour of the specimens, the fracture surfaces and fracture energy values, measured during both initial testing and after consolidation, were compared. Complementary data on consolidants distribution were gained from cross-section analysis:

Fracture surfaces

The percentage of new failure created after second-phase fracture gave information on whether the fracture occurred within the bondline between the old fracture surfaces or in entirely new areas of the foundation. These results indicated whether the consolidants were efficient bonding agents for joints of the old fracture surfaces and whether they were likely to facilitate failure of new areas of the material. An example for a typical DCB specimen after initial and second-phase fracture is presented in Figure 2. The differences in the fracture path are readily discerned, clearly showing areas of new failure of the foundation layer and some failure within the bondline. A summary of the results for all specimen sets is presented in Figure 3.

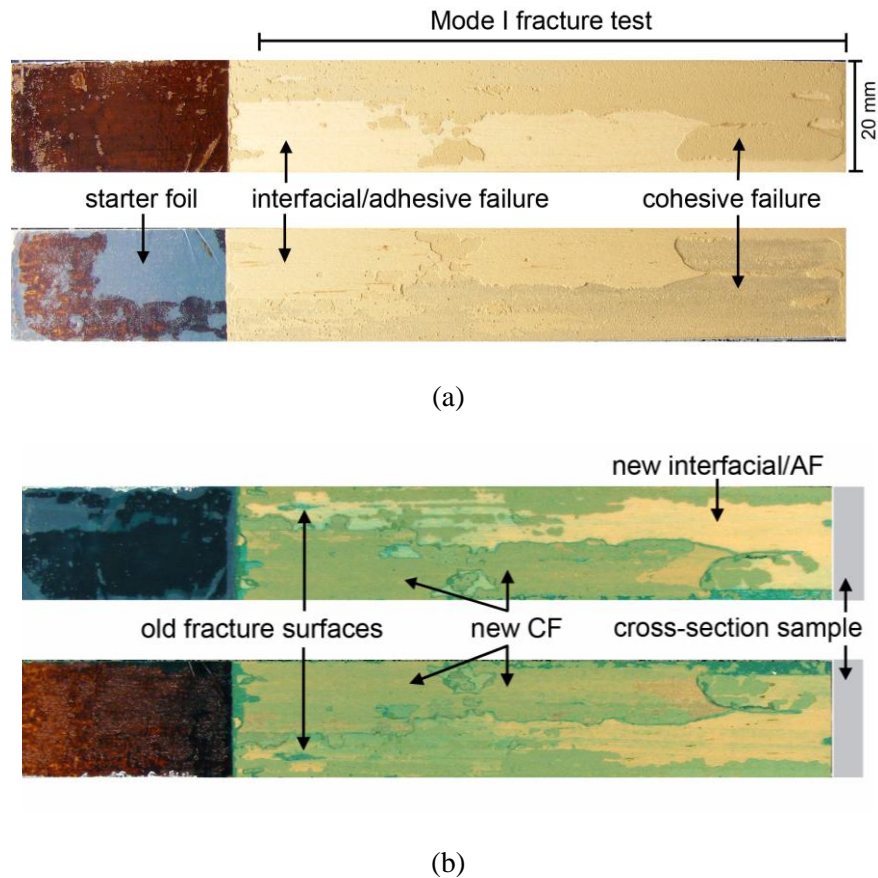


Figure 2. DCB specimen type B; (a) after initial fracture; (b) after second-phase fracture post consolidation with isinglass/starch stained with Fast Green. The fracture surfaces show a high proportion of cohesive failure (CF, fracture within the layer) partly within consolidated (green stained) and unconsolidated (unstained) areas of the foundation, as well as some new interfacial, i.e. adhesive failure (AF, failure between foundation and wood substrate), and some failure between the old, re-adhered fracture surfaces.

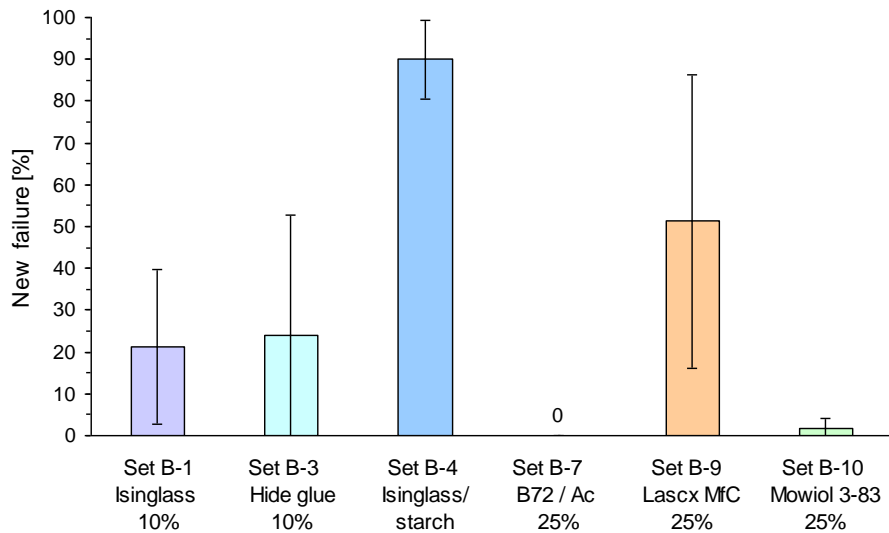
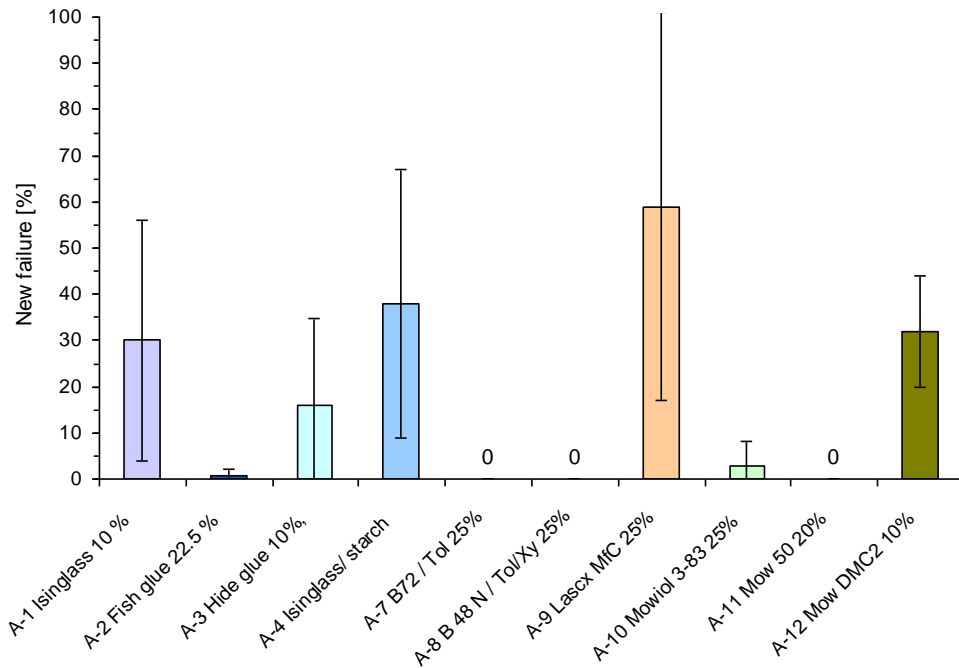


Figure 3. Percentage of failure in new areas of the DCB specimens recorded after second-phase fracture. The remaining failure developed within the bondline, following the fracture path from initial testing either within the bulk consolidant or within the joint starved of consolidant/adhesive. Error bars indicate \pm one standard deviation.

Fracture energy

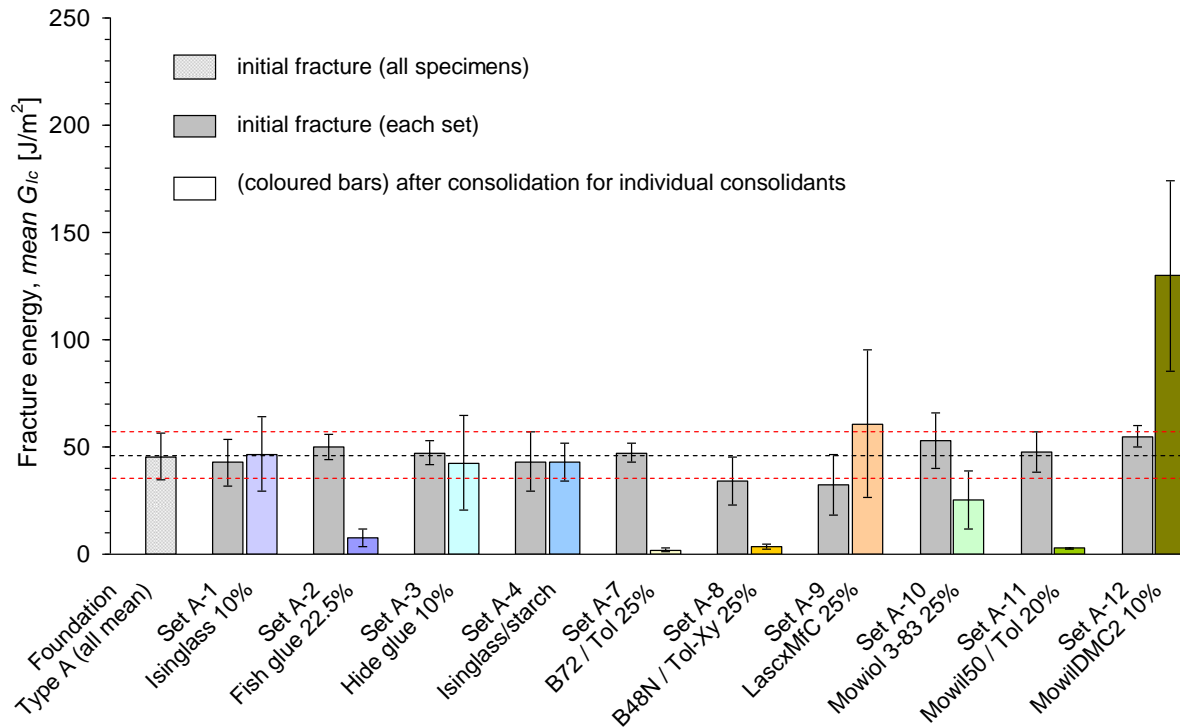


Figure 4. Mean fracture energy, G_{Ic} , values for each DCB specimen set of type A and B respectively, before and after consolidation. Error bars indicate \pm one standard deviation.

The average G_{Ic} values for all specimen sets before and after consolidation are summarised in Figure 4. The first light-grey bar in every chart represents the overall mean fracture energy of all DCB specimens of the respective type during initial fracture (46 and 47 J/m² for type A and B respectively). The pairs of dark grey and coloured bars refer to initial fracture and post-consolidation fracture for each set of specimens. The coloured bars indicate the general performance of the consolidants.

To eliminate the lack of randomness in these samples and to correct the absolute mean G_{Ic} values from the systematic error contained within, the relative changes in fracture energy (between each individual specimen), ΔG_{Ic} , were also compared, as shown in Figure 5.

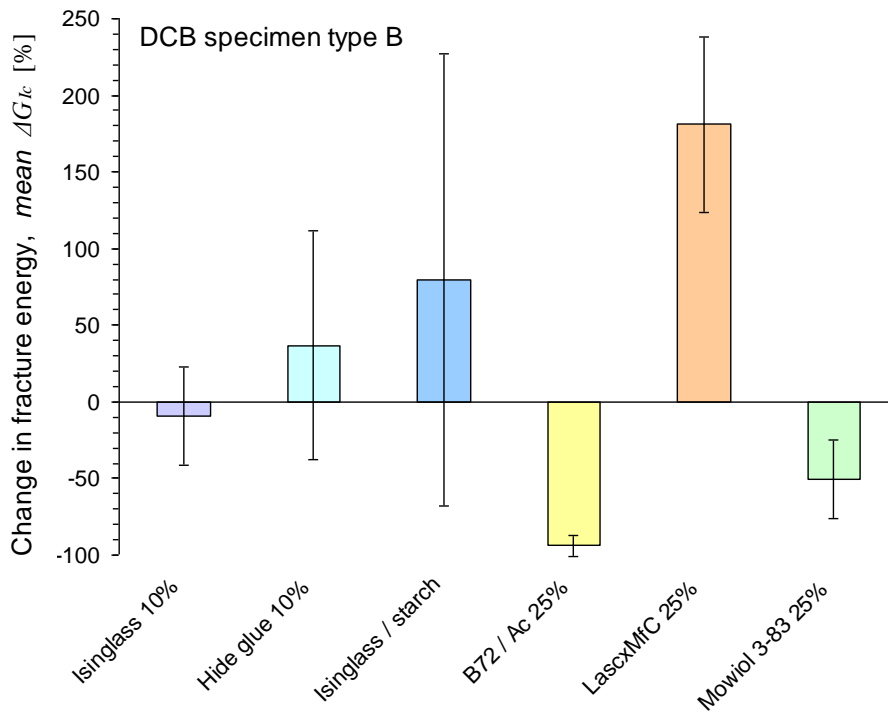
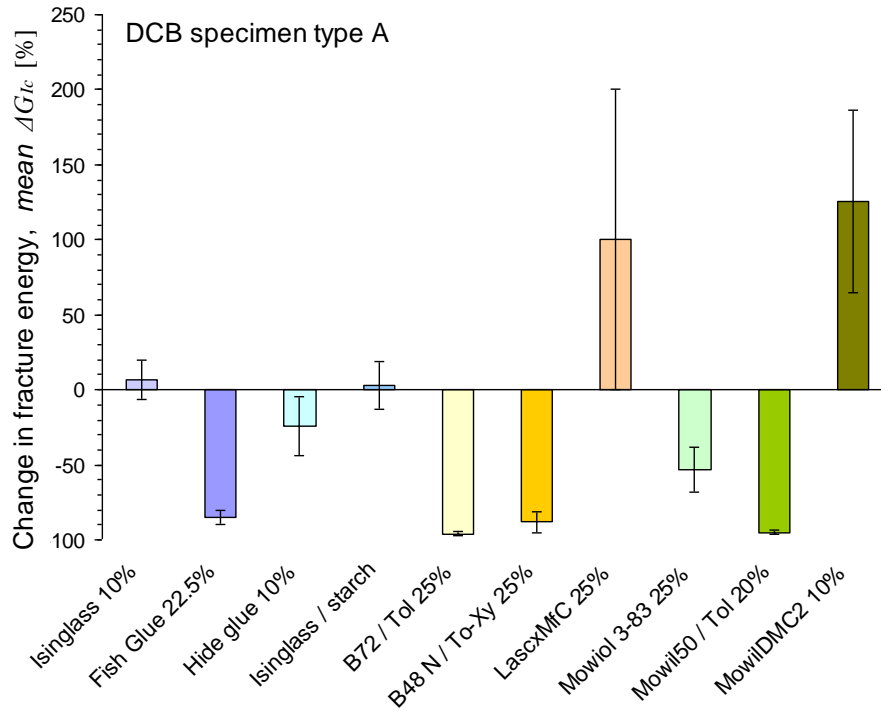


Figure 5. Effect of consolidants expressed as mean relative changes in fracture energy, ΔG_{Ic} , measured during second-phase DCB testing. Error bars indicate \pm one standard deviation.

From these bar graphs (Figures 3-5) it can be seen that the cold-liquid fish glue, the three Paraloid solutions and the Mowilith 50 all failed to strengthen the specimens. Fracture unanimously occurred only in the bondline, due to the consolidants' lack of adhesive and gap-filling abilities. Hardly any or virtually no failure occurred in previously unfractured areas of the specimens consolidated with fish glue and Paraloid, respectively. Paraloid B72 dissolved in acetone (type B) showed almost identical results to those of the Paraloid formulations dissolved in the benzenes. In these limited tests, the polarity of the solvent did not appear to have much of an influence on the mechanical performance of the consolidants at the given solution concentration of 25% resin content.

The PVAL Mowiol 3-83 displayed some degree of strengthening ability, despite not being able to restore G_{Ic} to the original level measured during initial fracture. Results for types A and B specimens were practically the same, both showing failure almost entirely within the bondline and at G_{Ic} levels of around half their original value.

The remaining protein-based consolidants (except for the cold-liquid fish glue) showed partly similar and partly differing performance:

For type A specimens, all the consolidants showed overall fracture energy values more or less within the range measured during initial fracture. As would be expected, only the scatter of the data tended to be larger after consolidation. The ΔG_{Ic} values for types A specimens were generally small.

For type B specimens behaviour of the protein-based consolidants differed from type A. Isinglass and hide glue appeared to show opposite results for ΔG_{Ic} , although the respective positive and negative changes were very small and cancelled each other out when the average value for both specimen types was considered. Both consolidants also showed similar amounts of fracture in new areas of the specimens. However the isinglass/starch achieved exceptionally high levels of new failure in the type B specimens, also reflected in the significantly higher fracture energy values for the type B specimens compared with type A. The higher mean fracture energies for type B specimens than for type A suggested that the longer equilibration times for these specimens played a significant role.

By far the highest average increases in G_{Ic} were measured for the polymer dispersions Lascaux Medium for Consolidation (acrylic) and Mowilith DMC2 (PVAc-based). Levels well above 100% of their original value were reached for type A specimens, whilst for type B the Lascaux MfC even showed mean increases as high as 180%. Lascaux MfC displayed an overall greater percentage of fracture in new areas of the foundation, compared with Mowilith DMC2. Together with greatly increased fracture energy relative to that of the unconsolidated foundation, this implied that the Lascaux MfC had not only re-adhered the fracture surfaces well, but had also effectively strengthened the foundation layer far beyond its original strength properties.

Again, the largely increased G_{Ic} values for Lascaux MfC type B specimens were attributed to the longer equilibration time of the samples. The mechanical properties of polymer dispersions were shown to change significantly during the first (at least 3.5) months after application.

Penetration behaviour

Complementary qualitative indication of the consolidants' performances was gained by assessing the bondline thickness and penetration ability of the consolidants by cross-section microscopy of the specimens. Penetration depth was ascertained on micrographs by evaluating the distribution of the individual stains used. Intense- or dark-coloured areas were interpreted as containing a high consolidant concentration, and areas appearing lighter-coloured as containing lower concentrations. Average foundation layer thickness before consolidation for types A and B was 0.32 mm and 0.30 mm respectively (excluding lacquer and epoxy resin layers). Examples of typical cross-section micrographs are presented in Figure 6. These show a specimen type B consolidated with isinglass/starch, and a specimen type A consolidated with Lascaux MfC.

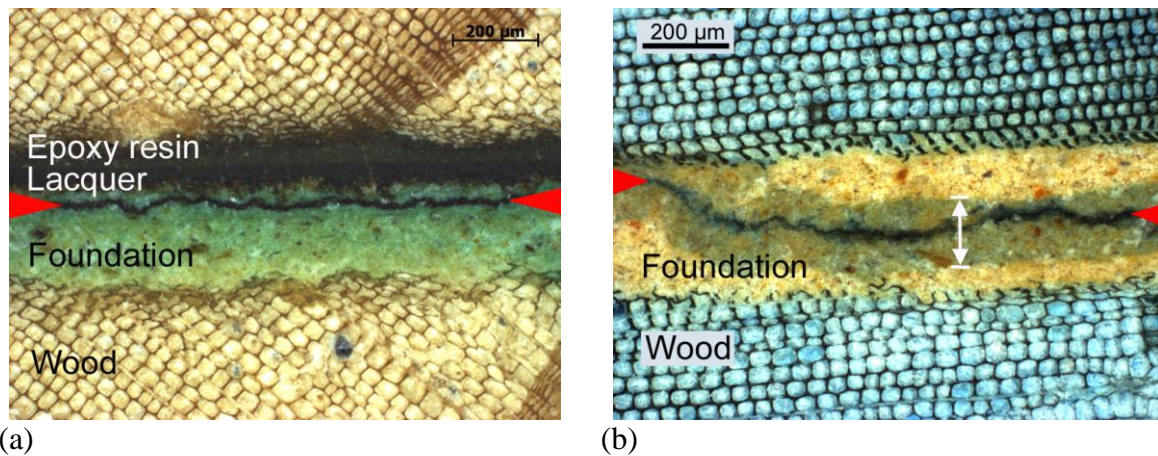


Figure 6: Cross sections of DCB specimens; (a) consolidated with isinglass/starch, stained with Fast Green (type B specimen), showing almost complete penetration of the stained consolidant through the entire foundation layer down to the wood interface; and (b) consolidated with Lascaux Medium for Consolidation, stained with Solvent Blue G (type A), showing more limited consolidant penetration (grey-blue zone) marked with white arrows. Red arrows mark the bondline between re-adhered fracture surfaces.

Broad trends of consolidant bondline thicknesses and penetration depths were established for each DCB specimen set and the results are summarised in Table 2. The data give the overall mean results for both specimen types A and B. This summary clearly shows that the non-aqueous consolidants mostly displayed insufficient adhesive bonding between the fracture surfaces and thus failed at the given concentrations as effective consolidants for fractured foundation layers. The protein-based consolidants that were applied as warm solutions, i.e. hide glue and isinglass, showed ideal properties in that they induced the fracture surfaces of the foundation layer to fit perfectly (due to softening of the layer). Also, they did not develop visible bondlines consisting of bulk polymer that could adversely influence the even distribution of mechanical properties in the consolidated layer. The isinglass/starch mixture showed both deep penetration and a significant bondline due to its two-phase composition of dissolved protein and dispersed agglutinated starch. The most efficient gap-fillers were the Mowilith DMC2 and the Lascaux MfC, which also achieved the highest fracture energy values. However, despite this similarity and a much lower polymer content of the DMC2 dispersion (10%), they showed rather opposing penetration behaviour, owing to greatly varying particle sizes (MfC $\sim 0.3\text{-}2.0\mu\text{m}$ and DMC2 $\sim 0.03\text{-}0.3\mu\text{m}$; see Hedlund and Johansson 2005; Lascaux).

Table 2. Summary of penetration and fracture behaviour of consolidants. (Mean values for type A and B specimens).

Consolidant	Solvent/diluent	Concentr. [wt%]	Bondline thickness [μm]	Penetration depth [μm]	Gap filling ability	Fracture energy G_{Ic} [J/m^2]	Bond-line failure [%]
Isinglass	water	10	-	130-170	n.a.	53	75
Fish glue	water	22.5	starved joint	100-200	poor	8	99
Hide glue	water	10	-	100-250	n.a.	48	80
Isinglass/ starch	water	13.3	10-20	130-270	excellent	66	36
Paraloid B72	toluene	25	starved joint	200-320	poor	2	100
Paraloid B72	acetone	25	starved joint	100-200	poor	4	100
Paraloid B48N	toluene/ xylene (1:1)	25	starved joint	200-320	poor	3	100
Lascaux MfC	water	25	20-40	100-160	excellent	109	45
Mowiol 3-83	water	25	10-20	60-250	good	22	97
Mowilith 50	toluene	20	starved joint	200-320	poor	2	100
Mowilith DMC2	water	10	30-180	30-50	excellent	129	68

The overall summary of the results is shown in Table 3. Such a table provides a good supporting tool for choosing consolidants with useful fracture properties for foundation material, as fracture energy values and their changes and the distribution of failure loci can be directly compared:

If it is required to re-establish the previous fracture behaviour of the material, a consolidant has to be chosen that can induce similar fracture energy levels after application. This criterion is fulfilled by the isinglass and the hide glue, which also showed at most 25% of new failure that occurred in both unconsolidated and consolidated areas of the specimens. This behaviour suggested relatively uniform fracture properties throughout the foundation layer comprising both unconsolidated and consolidated areas. Such consolidants would thus be desirable if a fragile material were to be stabilised with less potential for future damage in new areas.

Consolidants that induce very low G_{Ic} values due to starved joints (e.g. Paraloid, Mowilith 50) may not practically be useful, as fracture will reoccur when the least amount of energy is added to the system. Such energy levels are easily reached (and exceeded) during ordinary object

handling. Despite inducing relatively low G_{Ic} values, the Mowiol 3-83 may however still have useful properties. This formulation has the advantage of failing reliably and almost entirely within the bondline, whilst providing some, albeit small, degree of stabilisation. Thus, if reliable fracture within areas of previous damage is categorically desired, a consolidant like Mowiol 3-83 may be an appropriate choice.

Similar considerations apply to the consolidants that greatly increase G_{Ic} of the stabilised foundation, i.e. Lascaux MfC, Mowilith DMC2, and (to some degree) isinglass/starch. Such high strength improvements may be desirable in specific cases, e.g. where layers are particularly load-bearing. However, if these consolidants fail to disperse evenly within the structure, they pose the risk of creating within the specimen areas with very different mechanical properties that might induce further damage with time. This highlights that it is vital to choose consolidants on the most appropriate balance of properties, rather than a single criterion.

Table 3. Summary of the consolidant performance for protein-bound foundations of East Asian lacquer coatings.

Consolidant	Solvent	Concentration [wt%]	Effective adhesive	Effective penetrant	Toughening effect
Isinglass	water	10	+	+	0
Fish glue	water	22.5	x	+	-
Hide glue	water	10	+	+	0
Isinglass/ starch	water	13.3	++	+	+
Paraloid B72	toluene	25	x	++	--
Paraloid B72	acetone	25	x	+	--
Paraloid B48N	toluene/ xylene (1:1)	25	x	++	--
Lascaux MfC	water	25	++	+	++
Mowiol 3-83	water	25	+	+	-
Mowilith 50	toluene	20	x	++	--
Mowilith DMC2	water	10	++	x	++

Fields marked with '+' and '++' specify whether adhesive properties and penetration ability are good or very good, respectively. In the same columns, 'x' indicates the lack of effective adhesion or penetration. The toughening effect refers to the change in fracture energy, ΔG_{Ic} , induced by consolidation and is distinguished by '0' (more or less unchanged), '+' (increased), '++' (much increased), '-' (reduced), and '--' (starved joints which gave low G_{Ic} values under these conditions).

Conclusions

This research clearly showed that measurable differences exist between the mechanical performances of the individual consolidants. With respect to restoring the fracture properties of protein-bound foundation layers of export-type lacquer coatings, the most promising results were achieved by the isinglass and hide glue solutions. Addition of starch to isinglass increased G_{Ic} of the foundations as it provided very effective bonding in the joints. Mowiol 3-83 showed

some degree of strengthening, but provided only half of the original fracture energy of the foundation in the bondline, inducing failure entirely in the bondline. All consolidants based on polymers dissolved in hydrocarbon solvents failed at very low loads between the re-adhered old fracture surfaces due to consolidant starvation. They thus proved to be unsuitable for consolidating fractured foundation layers, when used in a single application at the given solution concentration. Mowilith DMC2 and Lascaux MfC demonstrated very effective bonding between the re-adhered fracture surfaces, inducing large increases in resistance to fracture. DMC2 lacked penetration ability and appears unsuitable for consolidating foundation layers, whilst Lascaux MfC showed very promising strengthening potential.

These data demonstrate that the methodology used has a wide scope for gaining a much improved understanding of the fracture behaviour of fragile foundation layers and the strengthening ability of different consolidants. This approach is therefore a promising tool for providing further selection criteria for suitable consolidants, complementing those already used in conservation, such as the consolidants' chemical stability, resolubility, appearance and handling properties.

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Materials and Suppliers

Araldite 2015 (epoxy resin)
Huntsman Advanced Materials Americas LLC
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Bovine Hide Glue (cubes), 63020
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Fast Green stain (C.I. 42053), 104022
Merck, Darmstadt / Germany
www.merck-chemicals.de

High-Tack Fish Glue (cold water fish protein), 56K60.01
Lee Valley Tools Ltd., Ottawa / Canada
www.leevalley.com

Lugol's (iodine-potassium iodide, I₂KI) solution, 109261
Merck, Darmstadt / Germany
www.merck-chemicals.de

Lascaux Medium for Consolidation (aqueous dispersion of acrylic ester + methyl acrylate ester + styrene), 81012
Mowilith 50 (polyvinyl acetate), 67040
Mowilith DMC2 (aqueous dispersion of vinyl acetate + maleic acid di-n-butyl ester), 76582
Kremer Pigmente, Aichstetten / Germany
www.kremer-pigmente.de

Mowiol 3-83 (polyvinyl alcohol), 2517100
Deffner & Johann, Roethlein-Schweinfurt / Germany
www.deffner-johann.de

Paraloid B48N (methyl methacrylate/butyl acrylate + dibutyl phthalate + adhesion promoter), 67470
Paraloid B72 (ethyl methacrylate/methyl acrylate), 67400
Salianski isinglass (dried sturgeon swim bladder), 63110
Kremer Pigmente, Aichstetten / Germany
www.kremer-pigmente.de

Shofu for Restoration (precipitated wheat starch)
Paper Nao 4-37-28 Hakusan Bunkyo-ku
Tokyo 112-0001, JAPAN

Solvent Blue G (C.I. 61554)
Town End (Leeds) Plc, Leeds / UK
sales@dyes.co.uk

Loctite Super Glue Gel (cyanoacrylate adhesive)
Henkel Corporation, Rocky Hill, CT / USA
www.loctiteproducts.com

Tonoko (Japanese clay powder), 716362
DICK GmbH, Metten / Germany
www.more-than-tools.de

Author Biographies and Contact Information

Nanke C. Schellmann is a conservator for furniture, musical instruments, and decorative objects, with a specialization in mixed materials and the characterization and treatment of degraded decorative surfaces. After training as a violin maker, she gained several years of work experience in the conservation departments of major museums in both Germany and the United Kingdom, and received an MA in Conservation from the Royal College of Art / Victoria and Albert Museum (RCA/V&A) Joint Conservation Programme, London. She has since worked in a private conservation studio, the V&A, and has undertaken additional studies in natural sciences at University LMU Munich. Currently, she is in the final stages of her PhD studies at the Academy of Fine Arts Dresden, in collaboration with the V&A Mazarin Chest Project and Imperial College London, investigating the changes in mechanical/fracture properties of porous, gesso-type foundation layers in multilayered East Asian lacquer coating structures induced by various consolidants.

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Ambrose C. Taylor is a senior lecturer in the Department of Mechanical Engineering, Imperial College London, and specializes in the characterization and modelling of thermoset polymers. Over the course of his career, he has held a prestigious Royal Academy of Engineering Postdoctoral Research Fellowship and a Royal Society Mercer Award for Innovation; authored about 50 journal papers and book chapters; investigated the fracture, impact, and durability performance of structural adhesives; developed novel adhesive and composite materials using polymeric and inorganic tougheners; and investigated the structure/property relationships of polyester-melamine coatings, the durability of asphalt, and the aging of East Asian lacquer. Much of his current work is investigating the structure/property relationships of thermoset polymers modified with nano- and micro-particles. This work involves extensive microstructural analysis, including statistical description of particle dispersion and clustering. These materials are used as adhesives and as the matrices for fibre composites.

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Ambrose C. Taylor est maître de conférence au département de génie mécanique de l'Imperial College London, et il est spécialiste de la caractérisation et de la modélisation des polymères thermodurcissables. Sa carrière a été ponctuée de hauts faits : la Royal Academy of Engineering lui accorde une bourse de recherches postdoctorales, il est lauréat du prestigieux *Brian Mercer Award for Innovation* de la Royal Society, il rédige une cinquantaine d'articles scientifiques et chapitres d'ouvrages savants. Il a étudié la résistance à la rupture et aux chocs et la durabilité des adhésifs structuraux, créé de nouveaux matériaux adhésifs et composites à base de durcissants polymères et non organiques et examiné les relations structure-propriété des enduits de polyester-mélanine, la durabilité du bitume et le vieillissement de la laque est-asiatique. La plupart de ses travaux portent en ce moment sur les relations structure-propriété des polymères thermodurcissables modifiés par des nanoparticules et microparticules. Dans le cadre de ses travaux, il réalise des analyses approfondies de la microstructure, ce qui comprend la description statistique de la dispersion et de la concentration des particules. Ces matériaux sont utilisés comme adhésifs et comme matrices pour les composites à base de fibres.

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