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Technical Paper 11

Scottish Renaissance Interiors: Facings and adhesives for size-tempera painted wood

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FOREWORD

Historic Scotland's Internship & Fellowship Programmes exist to increase the fund of skill and knowledge in relation to the needs of the built heritage in Scotland. This is achieved by providing a grant to individuals to allow them to gain experience in undertaking research and working with a specialist mentor. The aim of that investigation is to look at a particular topic in detail. The Internship & Fellowship Programmes have been running for over a decade in various forms, and have achieved an international reputation. However, the overall programme is intended to build capacity in Scotland in the medium to long-term and aims to look at particularly complex Scottish conservation issues.

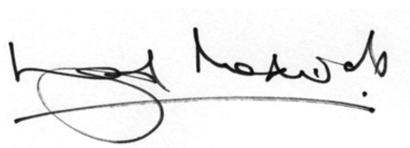
In undertaking this Research Internship, Chantal-Helen Thuer was mentored by Ray Hemmett of Historic Scotland's Conservation Centre. Having graduated from the London Guildhall University with a BSc degree in Conservation and Restoration of Decorated Surfaces she went on to gain a Diploma in Conservation and Restoration of Easel Paintings and Polychrome Wooden Sculptures at the Berne University of the Arts. Having already achieved some specialist knowledge appropriate to the discipline, the grant enabled her to gain additional knowledge and develop practical skills that built upon the theory and experience of her formal training.

In this volume, 'Scottish Renaissance Interiors: Facings and adhesives for size-tempera painted wood', Chantal offers an excellent example of how the programmes' intentions can be realised.

In the research report, the introduction outlines current dilemmas in the effective conservation of Scottish Renaissance Interiors surfaces, and sets the scene for the research work that was carried out under the auspices of the Internship. It specifically looks at the areas of most concern for the practising conservator – what appropriate facings should be used for the transport, emergency treatment and during the actual conservation work itself. Putting these aspects into their environmental context, a review is presented of current and past practices, and details of these are fully revealed, with numerous references taken from available published sources and the oral material gleaned during the study. Given that many records of previous casework projects do not adequately describe the details about the materials that were being used in the process; this is itself an important summary. This is ably put into an international context leading to a summary of the current position whilst also pointing out the likely way forward for practitioners.

In dealing with the choice of the different adhesives and facing materials available to conservators that they might use, the report considers how they should be thought of symbiotically. Putting this approach into the wider context, the results of accelerating aging and other tests are revealed, along with their consequences and limitations.

This is a highly specialised, but much needed, report into the topic. Whilst it will mainly appeal to the scientific and paint conservation communities, its findings should work their way into practice following this release of the study results. Supported by a robust bibliography, the overall findings will be of considerable value in addressing the future conservation needs of Scotland's tempera painted Renaissance interiors. With able mentoring by Ray Hemmett, Chantal-Helen Thuer is to be congratulated on dealing with the issues so effectively during her Research Internship with us.



Ingval Maxwell, OBE
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Historic Scotland
28 July 2008

INTRODUCTION

1.1 DEFINING A FRAMEWORK FOR THE RESEARCH

The purpose of a facing is to prevent damage during treatment, storage or transport. Most facings are meant for safekeeping paint layers.

Historic Scotland has in its care a number of Renaissance size-tempera structural paintings, both in storage and *in situ*. The standard method for many years now of providing secure facing protection either in preparation for later treatments or long term storage relies mainly on the application of a facing layer, Eltoline tissue, secured with gelatine (illus. 1). The latter use is very important because in most cases it is impossible to brush on an adhesive, because of the fragile flaky and powdery paint layer.

Illus. 1 Application of a gelatine facing to panels from the Riddle's Court ceiling on Lawnmarket, Edinburgh 1964

For decades facings have been used successfully for this purpose in all areas of conservation, but facings can endanger surfaces in several ways.[1]

During application damage might occur though flattening and/or displacing tenting flakes, adhering them in wrong positions. If left on for too long, the facing adhesive can become hard to dissolve, making the facing difficult to remove without damage to the surface. This can even happen with a frequently used adhesive like gelatine. For those reasons the recent use of facings has been a reluctant one, at least, as far as painting conservation is concerned.[2] Instead, research has been centred on circumventing facings altogether or finding alternative materials.

[1] Bradley (1950), chapter 4.02.

[2] oral information Renate Kühnen, head of paintings and polychrome sculpture conservation Berne University of the Arts - 2007

Considerations about the use of a facing should always include weighting the necessity of applying a facing against the impact on the paint layer of heat, solvent, mechanical action and shrinking of facing material or adhesive, which go with the treatment.

In terms of the conservation of matte paint on building structures the use of facings is also strongly linked to the consolidation and cleaning.[3] The approach with gelatine as a consolidant had been advocated by the Getty Conservation Institute and several other institutions.[4] However, there is anecdotal evidence that when used in the field by practicing conservators the system is often reported to be unreliable when supporting flaking paint or friable pigment surfaces by not providing adequate conformation of the facing tissue to the paint layer, but this has not been confirmed experimentally.

Migration of the adhesive into the substrate was also a problem with other adhesives, especially synthetic ones, restricting consolidation adhesive options in further treatments. Surely on of the reasons Robson advises to avoid modern materials if possible.[5] Facings often become difficult to remove, with the tissue leaving accretions embedded in the fissures of the paint surface or the support.[6]

Change can also occur to the visual appearance of the paint layer after removal of the tissue when residues of non dissolved adhesive cannot be successfully cleared and impart a sheen that alters the surface characteristics of size-tempera media.

Since the area of research is vast it was decided to centre the research on size-tempera painted wooden ceilings.

1.2 PROJECT AIMS

The aim of the research is the development of a system that would identify an effective adhesive and facing material that could satisfy the standards set for conservation materials.

[3] Historic Scotland, Edinburgh / NIKU, Oslo
[4] Dorge; Howlett (1994), p. 449
[5] Robson (1999), p.54
[6] oral information Jorgen Solstad, paintings conservator NIKU Oslo – 2007 / Ailsa Murray, structural paintings conservator Historic Scotland Conservation Centre – 2007 / Fiona Allardyce, Scottish Wallpaintings Conservators - 2007

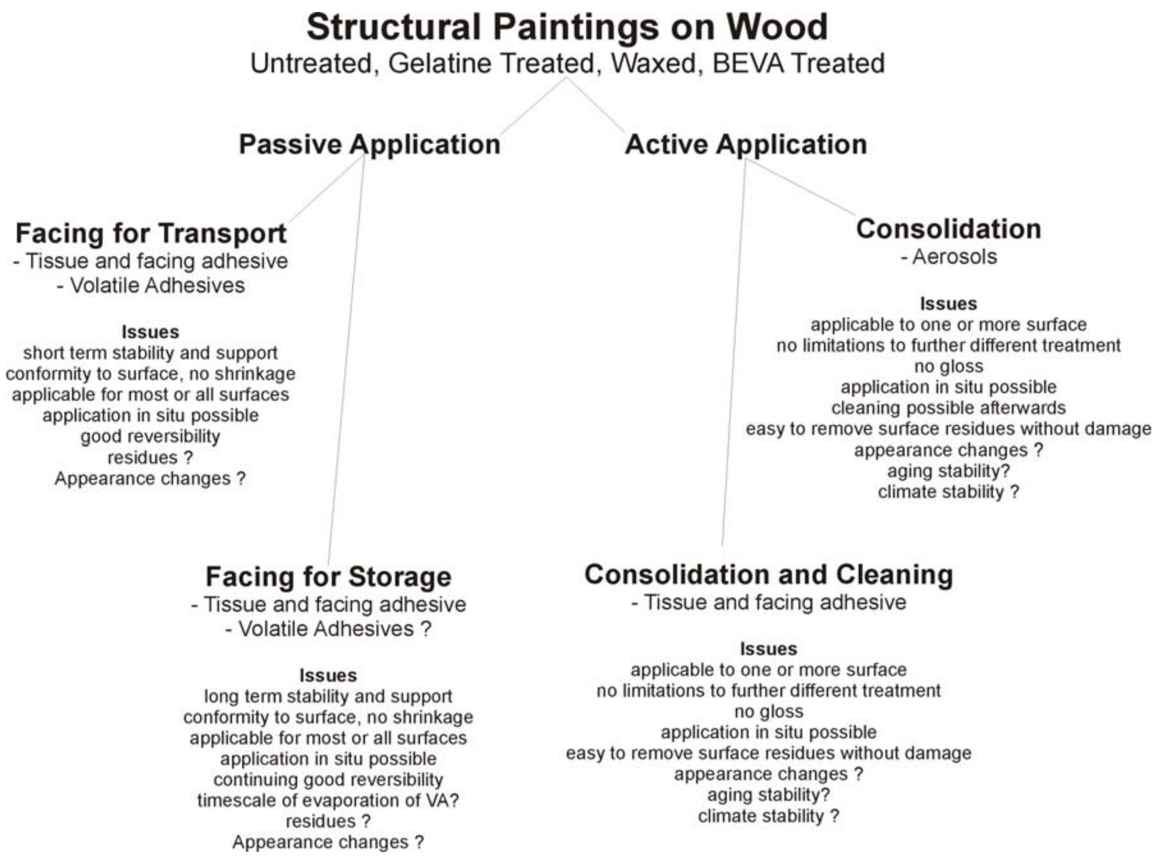
Literature research has shown that it is necessary to define the use of facing materials and consolidants in the conservation of size-tempera painted wood. The use and materials also has to be varied because of the different conditions the structural paintings come in: untreated, gelatine treated, BEVA treated and waxed. Wax and wax-resin coatings were mainly applied during the 1950s to 1970s to preserve the paint, unfortunately no consideration was given to the loss of matte appearance or the darkening effect of the aged wax layer (illus. 2).[7] On the other hand many structural paintings might have become lost completely without the protective wax layer. Fortunately no treatments have been executed with soluble nylon, which has become a problem on some structural paintings in Norway, because the darkened coat becomes irreversible, creosote applied against insect attack on others at least can be removed with tri-ammonium-citrate (illus. 3).[8] The mind map on the next page gives an overview of application areas that have to be addressed.

Illus. 3 Waxed ceiling at Aberdour Castle, Fife

Illus. 2 Remaining show square of a discoloured creosote layer on the ceiling of a 19th century guest house at the Norsk Folkemuseum, Oslo © Norsk Folkemuseum, Oslo

[7] Historic Scotland archive files; amongst those Aberdour, Gladstone's Land, Culross Palace

[8] oral information Jørgen Solstad, NIKU Oslo / Niels Gerhard Johansen, paintings conservator Norsk Folkemuseum Oslo - 2007



The main focus will be on facings for transport, emergency measures and during treatment, since these are of most concern.

Long-term facing solutions would apply to storage of parts from the salvage collection and for surfaces for which treatment has to be delayed for various reasons, such as legal and administrative issues. The salvage collection consists of painted ceilings which were rescued from (often to be) demolished buildings or fragments and laths which were too few to be reincorporated during refurbishments.

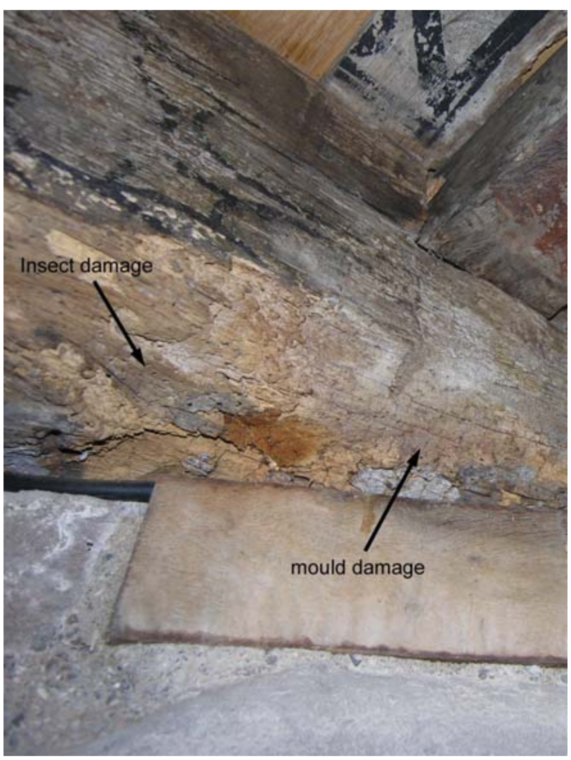
1.3 CONSIDERATIONS FOR SUITABLE MATERIALS

1.3.1 Climate

For the choice of adhesives, it was important to consider the normal climate of ceilings. Performance of adhesives can be compromised if they are not suitable for the predominant climate. Thus, it was imperative to collect climate data from sites with painted ceilings to determine which of the possible adhesives could withstand the conditions for a long time. Environmental monitoring data from different buildings with structural paintings both of Historic Scotland and the National Trust for Scotland was collected to establish a climatic overview of conditions for ceilings in a building and to find out, how they differ from the conditions at the storage facilities for the salvage collection. Furthermore, the accumulated climate data helped to set up an appropriate climate cycle for the weathering chamber. The relevant data is compiled on the Appendix CD.

The appraisal of the data showed that the climate in the vicinity of painted ceilings tended to be quite unstable and humid. Only two properties had an exceptional seasonal tendency to dryness, which was attributed to heating and public functions. Generally, the tested adhesives would have to deal with long-term humidity of about 60 - 95% RH and temperatures about 5 – 25°C. Near freezing temperatures in winter could be possible.

1.3.2 Microbiological Attack



Illus. 4 Beam end showing flight holes and old damage by brown cubical rot, Huntingtower Perthshire

Microbiological attack, namely pests and mould, are a common problem in the preservation of cultural heritage, especially in humid climate (illus. 4).
As climate logging in premises of Historic Scotland and the National Trust of Scotland have shown, the climates there can be quite attractive for microbiological attack and size-tempera and wood are an ideal food source. Paint layers may become less prone to microbiological attack due to degradation of the protein glue, but every facing and consolidation with this kind of glue would introduce a new food source.

Ideally an adhesive should be less attractive to microbiological attack or even discouraging it altogether. However, other considerations may be judged to be more important if the other properties of a facing adhesive out-weight this disadvantage.

1.3.3 pH-Changes

Another aspect is the influence of the adhesives' pH levels and the resulting effect this may have on paint layers. Research of the Canadian Conservation Institute has found quite significant changes in synthetic adhesives.[9] Thus, it was important to verify what kind of changes chosen adhesives would undergo in the predominant Scottish climate conditions since these changes could have a deleterious effect on pigments and binders.

pH readings taken from *in situ* paint surfaces and from those in storage have been compared to establish the 'comfort zone' the paint layer settled into over centuries. Adhesives whose pH remains neutral or within the 'comfort zone' before and after accelerated ageing would be most desirable.

1.3.4 Reactions with original materials

It is known that pigments can have influences on the behaviour of binding media. For example, research has revealed acceleration of degradation processes in the binding medium in connection to a certain pigment.[10] Similar processes may occur with other pigments and adhesives that are introduced into the paint layer as 'replacement binding medium'.

It is also be possible that introduced adhesives could accelerate deterioration processes within the paint layer during aging. Using standardised test panels with a range of common pigments will reveal any such reaction much more clearly than an original paint surface.

[9] Down et al. (1996), p. 39
[10] Schilling, Khanjian (1996), p. 126 / Fiedler (2001), pp.52-60

2. REVIEW OF CURRENT PRACTICES FOR FACINGS AND CONSOLIDATION OF MATTE PAINT

To get an overview of current practice and research about the subject, the latest literature both in English and German was reviewed. Additionally conservators at different institutions were asked to impart their experiences with facing techniques and consolidants for matte paint. Especially valuable was the information gathered from NIKU (National Institute for Heritage Research) in Oslo, since Norway has a long tradition of structural paintings on wood, painted with size-tempera (illus.5). The process and materials are virtually unchanged since the Middle Ages and so similar to the Renaissance size-tempera paintings found in Scotland that it allows a direct comparison of conservation methods.

Illus. 5 Painted underside of a beam-and-board roof in a wooden Norwegian house
© Norwegian Institute for Heritage Research, Oslo

Research into facings has not noticeably developed over recent years, since the technique seemed to be in a decline. Materials and techniques are mainly long established and changes occurred only, if a material proved to age badly or was ruled out by scientific research relating to other areas of conservation like adhesive testing for consolidation only. Development of alternatives using volatile adhesives took precedence. The most to be found on facings directly was in literature about paper conservation, because there it is still a frequent technique. In articles about lining paintings a lot of information could be found, that related to the use of those materials for facings as well. Over the years several treatments have surfaced, only to vanish again after a few years, like the facing method of Robert Fieux at the beginning of the 1980s, using a Teflon-coated textile with a silicon pressure adhesive. [11]

Research into consolidants for matte paint has a long history and is increasingly deepened by the increasing use of matte paints and powdered pigment by contemporary artists. While the US and Canada have done ground-breaking scientific research in this field, Scandinavia, Germany and Switzerland have become a recent driving force for further development, while in Norway and Sweden conservators are faced with extensive size-tempera painting on wood in stave churches and other historical sites and sculptures. Germany and Switzerland are both researching applications to consolidate size-tempera and matte paint in an increasing number of modern art works. There is also ongoing research at the University of Northumbria and the British Museum.

2.1 FACINGS

At Historic Scotland[12] apart from the gelatine and in the 1950s-1960s wax BEVA 371 has been applied as a consolidative facing in one case, where the painted ceiling had been formerly treated with wax. Examination last year revealed a predominantly matte surface without any apparent damages or discolourations after about 2.5 years even though the property has a cold and very humid climate. Since the windows of the room in the tower house are quite small, the amount of light on the ceiling is not excessive.
The BEVA had been applied in30% BEVA 371 in Stoddard Solvent has also been frequently used on easel paintings by Ray Hemmett over the years.[13]

At the British Museum various facings are used, depending on the object and the purpose of the facing, but in most cases they try to avoid it because of the disadvantages stated earlier. [14] For an

[11] Stoner (1994), p. 133
[12] oral information Fiona Allardyce, Scottish Wall Paintings Conservators, & Ailsa Murray, structural paintings conservator Historic Scotland – 2007 / Historic Scotland property file Huntingtower, Perthshire
[13] oral information Ray Hemmett, senior paintings conservator Historic Scotland - 2007
[14] Email Lynne Harrison, conservator of organic artifacts and lead in paintings British Museum – 2007

under-bound or powdering paint surface, consolidation is preferred rather than a facing. If the paint surface is cohesive but flaking, they would re-adhere the paint flakes rather than face the surface. However when they do face they usually use Japanese tissues and on occasion spun bond polyesters such as Bondina. This is a non-woven, chemically inert polyester tissue and is used in facings, linings and in wet processes. Similar non-wovens used elsewhere would be Reemay and Hollytex. Adhesives such as BEVA 371, Klucel G (20%) in IMS or water, or acrylic resins Paraloid B72 or B67 are applied very thickly to avoid penetration of the adhesive. In general they do not face for transport or storage, but consolidate powdering paint and re-attach flaking paint prior to transport.

Like their colleagues in London, conservators at the Norwegian Institute for Heritage Research (NIKU) and the Folk Museum in Oslo try not to use protective facings and if they do, it is mainly with isinglass as adhesive.[15] Considering the reversibility they share the same objections as Historic Scotland concerning gelatine. Unfortunately isinglass facings have also been found to become hard to remove after staying on for a long time. Thus, consolidation is always carried out first if possible. As opposed to Historic Scotland they do very seldom have to remove a structural painting from a building, so most work is done *in situ*. Also storage of boards and beams is not a big issue, since buildings that house the paintings are cared for as an entity, without removing painted interiors for any reason whatsoever. Historic buildings are not altered or disassembled now, leaving the structural paintings without "housing", if they were in the past, the painted parts would have been destroyed or simply stripped, being lost either way. This was especially true for the vast number of stave churches that has dwindled to a few.

Facings for consolidation on the other hand are frequently and successfully applied for consolidation much the same as at Historic Scotland (illus. 6). The isinglass is applied in a range of 0,5% to 3% through sheets of handmade Japanese tissue, which has proven for them to be much better than Eltoline, because of greater flexibility and wet-strength. They felt eltoline leaves something to be desired when used for spacious surfaces. From their point of view there are no objections to the use of isinglass due to ethical considerations like the conservators at the British Museum have, because they feel on such a wide scale more can go wrong with a synthetic adhesive and the properties of isinglass are well studied.

[15] oral information by conservators at NIKU and Niels Gerhard Johansen paintings conservator Norsk Folkemuseum in Oslo - 2007

The combination of isinglass and Japanese tissue has been used on the 17th century apse paintings in the Gol stave church at the Folk Museum. The treatment has been carried out about 20 years ago and it appears that there is nearly no flaking or powdery paint. There is no heating installed, but the climate in Oslo is quite moderate and it sits on a small hillside, removing it from the clay packed earth around, so they do not have problems with high humidity. On the other hand this is a serious issue for a small guesthouse with a fully painted size-tempera and oil interior. To battle high humidity levels a dehumidifier was installed last year as opposed to a heating, which would have affected the paint adversely. This method seems to work so far.

Illus. 6 Use of consolidation facings by conservators from NIKU, Oslo
© Norwegian Institute for Heritage Research, Oslo

The use of facings for paintings and papers is closely entwined at the conservation department of the University of Northumbria.[16] Their head of paper conservation, Jane Colbourne, supplied information about the techniques used both for paper and paintings and the ongoing research. Japanese tissue is the preferred facing material, whereas handmade tissue is given preference over machine made, because the handmade tissue expands more evenly in all directions. Interestingly thicker tissue is used for tented paint, since it moulds itself well to the surface and supplies a better support. In cases where the tenting is severe, the tissue is torn up into smaller bits (never cut, or it will tear easily from the cut edge inwards) and applied in slightly overlapping patches. The fringed edges prevent ridges, which could imprint themselves into the

[16] oral information Jane Colbourne, Head of paper conservation University of Northumbria - 2007

paint layer. Another way of moulding sever tenting is using Japanese tissue, that has been relaxed in heightened humidity. For additional support several layers of tissue can be layered.

As facing adhesive mainly no synthetic resins or emulsions are used. On paper the major adhesives are wheat and rice starch, but also Klucel G, Funori and sodium alginate. In some cases Bermacol, a hydroxyl ethyl cellulose, is taken. Gelatine is mainly rejected for its acidity. Colbourne also mentioned that an adhesive with high alkalinity might negatively affect dyes like indigo. Funori is mainly used in 3-5% solutions, but a question has risen about the percentages at Berne University of the Arts. It was found that seemingly higher percentages than 2-3% Funori not necessarily produced more adhesive strength, because of a limited amount of adhesive agent that can be dissolved from the algae substrate at any time.[17]

Cyclododecane has been tried both in paper and painting conservation, whereas disadvantages refer mostly to its application on paper as a non-rigid substrate. Otherwise it was found suitable, without giving specifics about the application methods and specific applications.

At the paintings conservation department of Glasgow Museums facings with Japanese tissue and isinglass, wax-resin or BEVA 371 are used, depending on the painting and situation.[18] Isinglass facings that had been applied to fragile paint surfaces for the duration of the refurbishment of the Kelvingrove Museum had been found soluble even after five years, whereas this was under controlled storage conditions. The paper conservators also use Japanese tissue, but their facings are mainly adhered with wheat starch or cellulose ethers.[19]

In the conservation department of the National Archives of Scotland facings are mainly adhered with gelatine, Funori or wheat starch with Japanese tissue being solely used as facing material and also other applications. The head of conservation, Linda Ramsey, kindly supplied a list of different tissues, mostly kozo, they order directly from Japan.[20]

Japanese Tissues

No.	Name	Size	Weight
1	Mr. Hamada’s Tengujo-shi	54 X 78 cms	5.5gsm
2	Usumino Nasu Kozo-shi	63 X 92 cms	6.8gsm&nb sp
3	Usumino Nasu Kozo-shi	63 X 92 cms	12gsm&nbs p

[17] oral information Renate Kühnen, head of easel paintings and polychrome sculpture / Nathalie Bäschlin, easel paintings and polychrome sculpture conservator Berne University of the Arts – 2005/2006

[18] oral information Polly Smith, senior art conservator Glasgow Museums - 2007

[19] oral information Tarn Brown, paper conservator Glasgow Museums - 2007

[20] oral information and email Linda Ramsey, Head of Conservation National Archives of Scotland, Edinburgh - 2007

4	Kurotani Kizuki Kozo-shi	60 X 90 cms	11.3gsm
5	Kurotani Kizuki Kozo-shi	60 X 90 cms	13gsm
6	Kurotani Kizuki Kozo-shi	60 X 90 cms	15gsm
7	Kurotani Kizuki Kozo-shi	60 X 90 cms	18.6gsm
8	Kurotani Kizuki Kozo-shi	60 X 90 cms	22.5gsm
9	Yuukyuu-shi Yuki sarashi	63 X 94 cms	10gsm
10	Yuukyuu-shi Yuki sarashi	63 X 94 cms	15gsm
11	Yuukyuu-shi Yuki sarashi	63 X 94 cms	22gsm
12	Tosa Kozo Senka-shi	64 X 98 cms	13gsm
13	Tosa Kozo Senka-shi	64 X 98 cms	21gsm
14	Tosa Kozo Senka-shi	64 X 98 cms	26gsm
15	Sugihara-shi Nagaban	36 X 136 cms	13gsm
16	Sugihara-shi Nagaban	36 X 136 cms	10gsm
17	Sugihara-shi Nagaban	36 X 136 cms	20gsm
Masumi roll 1	Kozo-shi	96 cm X 61 m	5.8gsm
Masumi roll 2	Kozo-shi	96 cm X 61 m	8.7gsm

Apart from the rolls the rest is handmade, which machine-made as they are differ in the way the tissue expands. The roll tissue has a higher expansion rate lengthwise because the making process allows for a greater alignment of long fibres alongside this direction.[21]

Two more recommendations for facings on matte surfaces came from Eddie Sinclair and Marie Buckley, House & Collections Officer at Newhailes in Edinburgh.[22] [23] Sinclair has used Tylose and Eltoline for a facing on a size-tempera surface, which was easy to remove and left to gloss or tide lines. Eltoline and Rabbitskin glue is currently used to face extensive flaking of coloured plaster walls at the Newhailes mansion. So far facings have been reversible after about two years and show no gloss or other problems.

The literature mainly reflects the choices named by the institutions above, divided into two groups, compilations of facing adhesives and case studies. The adhesives used with facings can be put into three categories: natural aqueous glues, cellulose ethers and synthetic polymers in their various occurrences. Amongst the compilations mentioning those categories as facing

[21] oral information Saho Arakawa, paper conservator National Archives of Scotland - 2007

[22] Marie Buckley, House & Collections Officer National Trust for Scotland at Newhailes, Edinburgh - 2007

[23] Eddie Sinclair, polychromy conservator; Presentation at the ICON conference on Polychrome Wood 26/10/2007

adhesives are Bradley, Rodgers, Kaufmann and Tobler. As facing tissues most commonly Japanese tissues, thin manila fibre tissue and sometimes synthetic non-wovens are used.

One of the earlier extensive sources for facing materials is Bradley in 1950.[24] His recommendations concerning facing tissues for paintings name Japanese tissues as the most commonly used facing material. The strength of tissues made purely out of kozo fibres is preferred to those made of gampi, mitsumate, hemp or other. If a stronger tissue is need for additional support he advises to take tissue made of zebu fibres. A more rigid facing support can be achieved by adding layers of blotting paper.
The choice of adhesives reflects the tradition on one side by using paste and wax-resin infusions, but also the modernism by including the synthetic adhesives PVAc and butyl methacrylate.

With Rodgers the difference between consolidants and facing adhesives is somehow blurred since she talks about consolidating, fixing and facing in paper conservation, but lists the adhesives as consolidants only. Facing tissues are not mentioned. [25]
Her spectrum of adhesives comprises starches (rice, wheat, Funori), gums (gum Arabic, gum tragacanth, tamarind seed gum), protein glues (gelatine, parchment size, isinglass, casein), cellulose ethers (methyl cellulose, sodium carboxy methyl cellulose, ethyl hydroxyethyl cellulose, hydroxypropyl cellulose) and synthetics (cellulose acetate, PVAc, soluble nylon, Paraloid B67/B72, praraffin wax, BEVA 371, Elvace 40-704, Rhoplex AC-234/Plextol 500).

The diploma thesis by Kaufmann is a study about facings for easel paintings and looks into the history of facings as well as into the more recently used materials. [26] Descriptions of materials are quite general and do not name any specific adhesives. He states that until the beginning of the 20th century aqueous adhesives were most commonly used, this could have been starches, starch-protein glue mixtures and in rare cases gums. Plasticisers and additives that would have often been added are not described further. In more recent times the spectrum seem to have grown with cellulose ethers, wax and synthetic dispersions down to solvent based synthetics. Kaufman also mentions various attempts to introduce films and tissues with pressure sensitive adhesives.
Major properties a facing tissue needs to have is softness and flexibility, leading to a quite extensive use of tissues and non-wovens. Again no specific tissue is mentioned, but its choice

[24] Bradley (1950)
[25] Rodgers (1988)
[26] Kaufman (1990)

referred to the object related situation, the function and application method the tissue needs to fulfil. Modern literature increasingly seem to introduce the complex facing, a layering of different tissues or tissues and textiles, to improve strength, protection and conformation to the surface. This kind of facing is even entering a 'high-tech' stage with the inclusion of an infinite range of modern synthetic materials like silicon, polyurethane foam, epoxy resins and honeycomb sheeting.

Another diploma thesis, that of Tobler, describes the damage caused by easel painting transfers, of which the facing is a vital part. [27] His research into modern facing materials revealed the use of not only tissues, but also polyester non-wovens, synthetic textiles, synthetic films and an array of stiff materials.

Among the aqueous facing adhesives, protein glues and starch pastes have been in use for more than a century, while cellulose ethers and synthetic dispersions are a more recent addition. Complex facings or mixed techniques as Tobler calls them can incorporate natural glues, synthetics, tissues and fabrics. An example he gives is a facing of three layers of Japanese tissues with Paraloid B72 topped with a lens tissue adhered with protein glue and china clay. The reason for that seems to have been the wish to separate the facing adhesive from the transfer adhesive, which would have been starch paste, protein glue or a mix of both.

Recent non-aqueous facing adhesives mentioned by Tobler are wax-resin mixtures, vinyl acetates and acrylates.

A big problem with case studies was the fact that they mention a facing, but do not give any details about the materials used. One of the few case studies actually mentioning the facing tissue and adhesive is that of a 17th century English panel painting done at the Victoria and Albert Museum. On a barrier layer of Ketone N varnish Eltoline tissue with BEVA 371 was applied.[28]

At the Optificio delle Pietre Dure e Laboratori di Restauro in Florence an oil painting that had been submerged in floodwater for the most part in 1966 was partially faced with Paraloid B72 and tissue during extensive works on the wooden substrate.[29]

To avoid most problems which are connected with facings the volatile adhesives were introduced into conservation a bit more than a decade ago. Volatile adhesives came directly from industrial

[27] Tobler (2000), p. 21-27
[28] Mills (2000), p.1
[29] Castelli (1998), p. 331

applications, sought for their hydrophobicity, non-toxicity and ability to sublimate without residues from a surface after a given time, literally 'vanishing into thin air'. This removed the need for facing tissues and potentially damaging removal of a tissue facing. Cyclododecane is the most used, but there are also industrial menthol and tricyclen-camphen, which have slightly different properties.

One of the first application areas was wall paintings conservation, especially fragile and water-sensitive plasters and frescos. Quite supportive facings could be achieved for big flakes by adjusting the thickness of the film while on the other hand water-sensitive paint layers could be impregated for aqueous surface cleaning or varnish removal. In Germany Michael Hangleiter is most associated with researching the use of volatile adhesives for wall paintings and has published concise articles about their use and characteristics.[30] A few years ago cyclododecane was used by conservators from the Bavarian Federal Office for the Preservation of Historical Monuments (Bayerisches Landesamt für Denkmalpflege) and Chinese colleagues to recover fragmented stone armour from the grave of the first Chinese emperor.[31] The fragment piles were thickly faced with the adhesive, which made it possible to remove it as a whole, and after the sublimation they could be catalogued in the laboratory in its original positioning.

More research has been done by Geller and Hiby in recent years into how polychrome surface and paper conservation could benefit from the advantages of volatile adhesives. [32] They did a lot of empirical testing to observe application methods, surface changes and penetration properties.

Volatile adhesives are currently undergoing further testing at the British Museum and the Ashmolean Museum.[33] [34]

Another approach to facings that had been tried by Fieux in the 1980s and has been used on textiles with different adhesives is using a pressure-sensitive contact adhesive.[35] Lascaux 360HV, an acrylic adhesive is a contact adhesive that is used for textile supports, so it would be interesting to see, whether it would work as a facing adhesive that would just need solvent removal, thus eliminating one of two wet treatments. [36]

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[30] Hangleiter (1998), Restauro Vol. 5 & 7 / www.hangleiter.com

[31] Catharina Blänsdorf / Sandra Bucher Fiuza, presentations at 'Beneath Yellow Soil', the International Symposium on the German-Chinese Collaboration on Protecting Cultural Assets in Shaanxi Province China– 21/04/2006

[32] Geller, Hiby (2002)

[33] Email Lynne Harrison, conservator of organic artifacts and lead in paintings British Museum – 2007

[34] Parkin (2005), p. 45

[35] Stoner (1994), p. 133

[36] Karsten, Down (2005), p. 927

2.2 CONSOLIDATION TREATMENTS FOR MATTE PAINT

The British Museum uses a divers selection of adhesives for matte paint, which is found a lot on ethnographical objects. [37] They use acrylic resins such as Paraloid B72 and B67 in an appropriate solvent, also Klucel G, Culminal and carboxy methyl cellulose where water is not a problem. Very low percentages are applied with a brush and sometimes an ultrasonic humidifier for water based consolidants.

Aquazol, Lascaux Medium for Consolidation and gelatine are mentioned as good adhesives for a cohesive flaking paint layer but by experience are not good for consolidation of under-bound or powdering paint. They use these materials and others, for example, acrylic dispersions (Primal B60A) and in the past Vinamul 3252, but generally do not use PVAs for consolidation now. They tend not to use gelatine as it is often the original glue in an artefact and would not be indistinguishable so could be misinterpreted. If there is a danger of staining of a matt surface then they usually wet out the surface with White Spirit before introducing the adhesive beneath the paint flake.

The conservators at NIKU and the Norsk Folkemuseum in Oslo have tried a variety of materials for consolidation.[38] From 1930s to 1960s gelatine, horn glue and rabbitskin glue were most frequently used, but found unsatisfactory both in terms of long term stability, drying tension, susceptibility to humidity and microbiological growth. Other materials, which were tried during the 1950s, included casein, beeswax and boiled linseed oil, but those altered the surface appearance radically. During the next two decades trials were made with a new material called Calaton CB, "soluble nylon", which was promoted as a good adhesive for matte paint at the time. Unfortunately it turned out to have bad ageing characteristics, becoming dark brown and insoluble, so it was discarded again.

Since an appropriate adhesive could not be found, more research was carried out during the 1990s, with the new additions of synthetic adhesives and, with a return to a traditional material, isinglass. A research project had been carried out around 1992 included 5% Paraloid B72 in p-xylene, 5% Plextol 500 in isopropanol, 4% Klucel EF in ethanol, 4% Klucel L in ethanol and 2,5% isinglass in deionised water. Of all those isinglass gave the best results and is still used for consolidation much in the same tradition as gelatine is in Scotland.

[37] Email Lynne Harrison, conservator of organic artifacts and lead in paintings British Museum – 2007

[38] oral information by conservators at NIKU and Niels Gerhard Johansen paintings conservator Norsk Folkemuseum in Oslo - 2007

Relatively recent tests included Lascaux Medium for Consolidation, since it is favoured by Swedish conservators for size-tempera, and Funori. For their taste, Funori is not strong enough an adhesive, but the Lascaux Medium worked perfectly for small areas, where it can be applied underneath flakes with a brush. It seemed problematic on wider scales through tissue, because it has a much shorter drying time than isinglass.[39] Often the tissue would stick to the surface before it could be removed. Therefore, the use of the Lascaux Medium is restricted to wooden sculptures and altarpieces.

Ultrasonic misting has been tried, but found not strong enough to adhere flakes properly.

At the University of Northumbria the consolidants for matte paint are fairly the same as for facing, keeping in mind that they are listed for paper conservation.[40] For painting conservation starch is rarely used unless as bulking agent for isinglass. Listed for use on matte paint on course handouts are the adhesives with varying success: Cellulose ethers, Funori, carrageen moss, sodium alginate, gums (for paper conservation), protein glues, PVAc, Paraloid B72, Elvace and Rhoplex AC-234 (other trade names: Plextol B500-D360 or Primal AC 634).

According to Marie-Louise Sauerberg Lascaux Medium for Consolidation has been used for the consolidation of the paint layer on the tester above the grave of the Black Prince in Westminster Abbey. [41] It was applied underneath the paint layer by brush and syringe as to leave no glossy residues. So far the adhesive seem to behave well under the conditions within the Abbey.

Literature's list of adhesives used for matte paint nowadays is quite diversified and reflects the choices of adhesives given during the interviews.

Despite the known disadvantages traditional natural adhesives are mentioned as often as cellulose ethers and other synthetic materials. Concerning matte powdery paint gelatine is widely used, as is isinglass.[42] [43] Rabbitskin glue on the other hand has been included in protein glue test series, but seems to play a lesser role in consolidation.[44]

Funori has been in use in Japan for centuries as an adhesive, but has only recently found its way into conservation outside, especially for matte paint and paper.[45] The purified version JunFunori

[39] oral information by conservators at NIKU in Oslo - 2007
[40] oral information Jane Colbourne, head of paper conservation University of Northumbria - 2007
[41] oral information Marie-Louise Sauerberg, paintings conservator Hamilton Kerr Institute - 2007
[42] Brænne (1987), p. 16 / Haupt ***et al.*** (1990), p.10 / Hansen et al. (1993), p.52 / Hofmann (1998), p. 55 / Przbylo (2006), p. 117
[43] Haupt *et al.* (1990), p. 10 / Hansen *et al*. (1993), p.52 / Kolbe (2001), p. 50 / Fischer (2003), p. 133
[44] Haupt *et al.* (1990), p. 10 / Hansen *et al*. (1993), p.52

by Lascaux, which was developed a few years ago is said by the manufacturer to surpass its natural source in qualities and is predominantly used by Swiss and German conservators at the moment.[46]

Cellulose ethers as a substitute for protein glues have found widespread use in paper and paintings conservation, offering different varieties with varying solvent solubility, viscosity and strength. The literature can be confusing at times, because cellulose ethers are known by a multitude of trade names often differing just by manufacturer with Methocel, Klucel, Tylose and Culminal amongst them. Most often Methocel and the Klucel types G and E are recommended for consolidation[47], while cellulose ethers seem to appear mostly as part of testing series[48].

Acrylic Dispersions are quite often used for their good penetration and adhesion. In Sweden for about 25 years size-tempera was predominantly consolidated with Acronal 300D until it was taken off the market as stated by Tangeberg.[49] The lack of an adhesive that produced similar satisfactory results was tackled by conservators around Hedlund who worked on the development of Lascaux Medium for Consolidation with Lascaux Colours & Restauro in Switzerland.[50] As discussed in the interviews earlier its use is continuously increasing.

The range of water- and solvent-soluble synthetic adhesives that is currently in use has grown so extensive that the Canadian Institute for Conservation subjected a great number to ageing tests, to verify the various ageing characteristics that had been questioned since they first were introduced into conservation.[51] Amongst those were PVAc, PVA, Paraloid B67 / B72, Plexisol, BEVA 371 and Mowilith, which were also named for consolidation of matte paint by Hansen.[52] An adhesive which is not widely known even though it has been in use for a while is Aquazol, available with three different chain lengths. The most concise information about it was compiled by Wolbers and Arslanoglu[53], although it is reported to have been used as consolidant in Estonia[54] and at Berne University of the Arts[55].

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[45] Hansen *et al*. (1993), p. 248 Masako Okabe / Brown (2002), p. 8 / Swider, Smith (2005), p. 122 / Grantham (2002), p. 58 / Masuda (1984), p. 128 / Michel (2002), p. 257
[46] Geiger, Michel (2005), p. 204, EMPA (2003) web articles / Ritter, Masson (2005), p.2
[47] Hansen *et al*. (1993), p. 60 / Emberger *et al.* (2002), p. 191 / Wosnitza (2005), p. 29 / Ibsen (1999), ConsDistList entry 24/11/1999 / Beiner (2001), ConsDistList entry 13/11/2001
[48] Feller (1990) / Waltriny (2003) / Güttler (2005) / Pataki (2007)
[49] Tangeberg (1997), p. 341
[50] Hedlund, Johansson (2005), p. 438
[51] Down (1996)
[52] Hansen et al. (1993), pp. 57-60
[53] Wolbers et al. (1994) / Arslanoglu (2003/2004)
[54] Sibul (2006), p.5
[55] observation of two treatments of modern art, one, a canvas painting, had shown peeling layers of chrome paint and unbound pigment

2.3 CONCLUSION

The information gathered from the literature research and interviewing conservators and searching the literature brought up a variety of possible materials. However, a tendency towards the use of traditional materials above modern synthetic ones can be detected. Having shown sometimes conflicting results as to their ageing properties, modern synthetics seem not to inspire trust as a facing adhesive.

Japanese tissues are used for their superior qualities, which are preferred even to Eltoline. Even though research has been done about other facing materials, the majority of conservators seem to return to Japanese tissues. Depending on the object, non-woven polyester textiles, like Reemay or Hollytex, or polyester meshes are used. This is especially true for paper conservation or lining paintings. Non-wovens and meshes are quite durable, but not particularly flexible, although they still might work as a facing for a more even surface in stable climate conditions.

The adhesives for facings tend to be the same as for consolidation. Some of those have to be ruled out for size-tempera painted wood, because of high film tension and gloss, such as gums. Starch pastes are very frequently used in paper conservation, because the treated papers normally do not return to environmental conditions, which might promote microbiological growth or pest attacks.[56] Other "traditional" adhesives used in the field include different protein glues and polysaccharide glues like Funori. Gelatine is used as well but more rarely. Both isinglass and gelatine are known to be problematic if they stay on for a long time.

New synthetic adhesives are also in frequent use, although the question of their ageing properties remains the centre of heated discussions. These include various cellulose ethers (Klucel, CMC, Bermacol, Methocel, Culminal, etc.), different solvent-based synthetics (Paraloid B67/B72, Lascaux range, BEVA 371, etc.) and synthetic emulsions (Lascaux Medium for Consolidation, Mowilith DMC2, Plextol, Acronal, etc.). Some of them are in use despite claims of bad ageing like Paraloid B67. The argument for using them is, that they are less likely to attract mould and pests, are more flexible and more stable and necessitate less repeated treatments. A disadvantage is that later treatment with aqueous adhesives might become impossible and the ageing characteristics are still questionable despite sometimes extensive testing, which is often a reason a

[56] Emmenegger (1997), p. 126

lot of conservators would only try them as a last resort. Even though most synthetics will produce gloss at higher concentrations, it is possible to use them with low concentrations on matte paint.
A consolidant, which is quite new, but tested to have good ageing characteristics, is Aquazol. It has been successfully used on matte paint and powdered pigment and does not block further aqueous treatment.

To avoid facings altogether, volatile adhesives have been adapted for conservation in the last decade. They started out for building and archaeological conservation, but found their way quickly into other disciplines as well, because they are very effective as a temporary facing to protect water-sensitive surfaces and loose flakes. The major advantage is their removal, simply by evaporation on its own, making the use of solvents, heat and mechanical action obsolete. This in turn means less stress for the object and the evaporation time can be manipulated by the way of application and covering.

3. CHOICE OF MATERIALS FOR TESTING

3.1 ADHESIVES

The following adhesives were chosen either for their successful use in different parts of conservation or previous testing and evaluations of their properties and ageing characteristics as found in literature and by interviewing conservators. Exception to the rule would be the SeaGel, it was included since there seem to have been not much testing done in comparison to other adhesives.

The protein glues have the drawback that they might become insoluble, prone to microbiological attack and RH sensitive, but they are still the most sympathetic adhesives and do not change the original appearance of the paint layer.[57] Secondly they do not introduce a new binding medium into the paint layer that could induce new problems. In some cases it might be preferable to work with a similar material and its known disadvantages than using a totally different one that could cause even more disagreeable surprises.

Algae glues are considered more flexible than protein glues as well as less prone to microbiological attack, because of their built in anti-microbiological activity.[58] Since it is considered a weak adhesive it should not put undue stress on the faced paint layer. It also hardly discolours the painted surface. Funori works well in the varying climate with often-high humidity that Japan favours.

The cellulose ethers are also often used as a substitute for protein glues, as they are also less prone to microbiological attack and considered more flexible, although they sometimes fare do not well in humid climates, depending on concentration and type of cellulose ethers. The chosen ones are of those types that showed promising qualities in Feller's[59] extensive testing of them with only the Blanose 7M8SF substituted for Feller's choice of Cellulose Gum 9M8. Blanose is the rebranded carboxy methyl cellulose with 7M8SF being closest to the original in properties.

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[57] Kolbe (2001), p. 48 / Zumbühl (2003), p. 98
[58] Swider, Smith (2005), p.120
[59] Feller (1990), p. 58

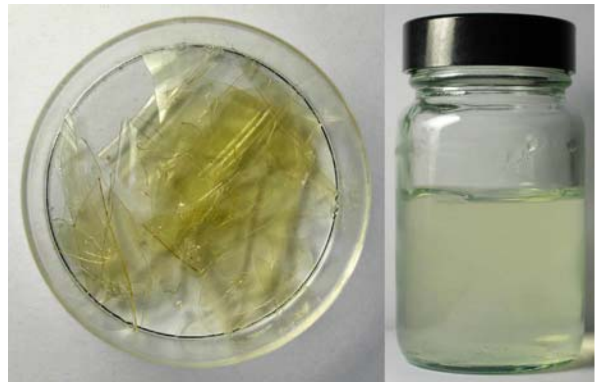
Since synthetic adhesives are a growing range among conservation adhesives different types of the most promising ones were chosen with Lascaux Medium being specifically developed for matte size-tempera surfaces. They were developed to be superior to natural ones in flexibility, re-solubility, ageing-resistance and microbiological resistance. On the other hand there are concerns that under some circumstances they could become insoluble with a deleterious influence on the paint layer, because it is felt that accelerated aging cannot replace the natural ageing of decades. It has also to be considered that they can never be fully removed from such a porous surface and often prevent further treatment with other adhesives, specifically aqueous ones. It remains to be seen if for some of them the advantages outbalance the deficits.

Volatile adhesives are a quite recent development and seem to perform better in terms of re-solubility since they are said to sublimate completely.

The following part gives an overview of the chosen adhesives and some general information about each of them.

Protein Glue	Gelatine, Isinglass, Rabbitskin Glue, SeaGel
Polysaccharide Glues	Funori, JunFunori, Sodium Alginate
Cellulose ethers	Methocel A4C, Blanose 7M8SF, Klucel G, Klucel E, Tylose MH300
Acrylic Adhesives	Paraloid B72
Acrylic Dispersions	Lascaux Medium for Consolidation, Lascaux 360HV, Mowilith DMC2
Other synthetic adhesives	Aquazol 50/200/500 (Poly-2-ethyl-2-oxazoline), BEVA 371
Volatile Adhesives	Cyclododecane, Menthol

GELATINE



GENERAL INFORMATION

Gelatine is derived from the protein collagen, which is the principal protein in animal hide, connective tissue and bones.[60] The collagen is treated with either acids or bases and then hydrolysed with heat and water. Today it is widely used in food and photographic industries, but it has been used for centuries as an adhesive and consolidant in hand-made form. Nowadays in conservation it is used in the standardised industrial grade.[61] Industrial grade gelatine comes in slightly yellowish sheets, granules and powders.[62]

PREPARATION

The necessary amount of gelatine needs to be soaked in cold water for at least 10 minutes before and can be heated up for dissolution. Sheets normally take less soaking time. The warm solution has a low viscosity and can be applied with a brush.

ISINGLASS

GENERAL INFORMATION

Isinglass, another protein glue, is extracted from the swim bladder of sturgeon and has been known since antiquity.[63] Its use in conservation has a long tradition as adhesive and consolidant with natural sturgeon supplying the bladders.[64] Today swim bladders are mostly harvested from farmed sturgeon,

[60] Zumbühl (2003), p. 95
[61] Haupt, et al. (1990), p. 10
[62] Wehlte (1992), p.228
[63] Przybylo (2006), p. 117
[64] Haupt, Dyer, Hanlan (1990), p.10

hake and cod in Finland, Russia and US, coming dried and in slightly different qualities. The highest quality isinglass comes from Russia.[65]

It is still frequently used in paintings conservation because of good tack, transparency, elasticity, hygroscopicity, continuous solubility and low overall tension, all of which are said to be superior to gelatine.[66]

PREPARATION

The preparation is normally done just once in a while to produce material for storage. Cut-up dried swim bladders are soaked in water for 24 hours and slowly cooked for several hours before it is strained. The strained solution is then poured onto melinex sheets and left to dry to a ready-to-use film (as seen in photograph), which can be torn up and stored.

The film bits need to soak for about 15 minutes in cold water before it is warmed up to liquefy the isinglass.

The warm solution can be worked like gelatine.

RABBITSKIN GLUE

GENERAL INFORMATION

Rabbitskin glue, belonging to the group of protein glues, is made as the name implies from rabbitskin and comes in small yellowish granules or pellets. In common with other animal glue, it has been in use for a long time and is preferably used by gilders.[67]

The properties are similar to gelatine and isinglass, although it is said to be a bit more flexible and has less adhesion.[68] Its use in painting conservation has declined, because it is considered not to be as pure as gelatine or isinglass.[69]

[65] Haupt, Dyer, Hanlan (1990), p.10
[66] Przylylo (2006), p. 117
[67] Conservation & Art Material Enyclopedia Online, Museum of Fine Arts Boston, http://cameo.mfa.org/materials/record.asp?key=2170&subkey=7737&Search=Search&MaterialName=rabbitskin+glue
[68] Mayer (1991), p.308
[69] oral information Prof Renate Kühnen, University of the Arts Berne - 2004

PREPARATION

Rabbitskin glue has to be soaked for about 10-15 minutes in cold water, pellets need longer than the small granules. After that the solution can be warmed up, until the glue is dissolved. Like the other protein glues it is then clear and slightly yellowish and will gel when cooling down, although it takes longer than isinglass.

It can be easily applied by brush.

SEAGEL

GENERAL INFORMATION

SeaGel is a liquid, cold fish glue, which is supplied commercially produced by CPC (Conservator's Products Company) and supplied by Conservation Resources Ltd. It is seen as an alternative to isinglass as a consolidant for paint flakes and as adhesive for paper, photographic materials and textiles with the advantage of being applicable in cold state.[70]

The commercial product is not the same as the original product, which was developed by Tatyana Petukhova and Dr Joe Regenstein of Cornell University (US). According to Petukhova the commercial SeaGel has more additives and performs different than the original one.[71] Since not much testing has been done to compare SeaGel to other adhesives, it was decided to include it to see how it performs under climate stress, considering the information Conservation Resources supplies claims it to be suitable for facings.

SeaGel contains purified fish gelatine (~13%), propylene glycol (~3%), potassium sorbate (~0.5%) and water (~83.5%). It is a light yellow liquid with a neutral pH and is soluble in water, though it can be diluted with alcohol and bulked up with starch. It is said not to fail under changing climate conditions.[72]

[70] instruction leaflet SeaGel by Conservation Resources (UK) Ltd.
[71] email Tatyana Petukhova - 2007
[72] instruction leaflet SeaGel by Conservation Resources (UK) Ltd.

PREPARATION

SeaGel is ready to use in cold as well as warm state and can be applied with a brush through the tissue. It must be stored in a cool place, but not in a fridge and it is wont to go off after six months.

FUNORI

GENERAL INFORMATION

Funori (Fu = sea, No = moss, Ri = fragrance) is polysaccharide mucilage, similar to carrageenan, made from the seaweed *gloiopeltis furcata*, which is harvested from natural populations in Japan. [73]

It is traditionally used by Japanese mounters and conservators as a consolidant for scroll paintings. Applied in relatively generous quantities its bulk is not apparent after drying and it appears matte.[74] Therefore it has proven itself as a suitable consolidant for matte flaky and powdery paint in general conservation. In the last few years conservators have taken a rising interest in it for use on paper, textiles, paintings and wooden sculptures.[75] An added bonus is the fact that because of its structure and composition Funori has an apparent antimicrobiological activity.[76] However, it does not mean Funori is impervious to attack, but less so than protein glues.

In an interdisciplinary project the consolidant extracted from the red alga species *Gloiopeltis* was investigated. In the project, the Empa (Swiss Federal Laboratories for Materials Testing and Research) cooperated with the Institute of Monument Conservation of the Swiss Technical University and the Centre of Conservation of the Swiss National Museum to assess the good properties of this consolidant.[77] Since it is considered a weak adhesive it is sometimes used in conjunction with isinglass to increase adhesion. Japanese conservators also use this technique.[78]

[73] http://aic.standford.edu/sg/bpg/annual/v03/bp03-05.html
[74] http://aic.standford.edu/sg/bpg/annual/v03/bp03-05.html
[75] oral information Jane Colbourne, Jørgen Solstad, Barbro Wedwik, Renate Kühnen - 2007
[76] Swider (2005), p. 20
[77] Geiger, Michel (2002), pp.257-275
[78] oral information Motoya Myochin - 2006

PREPARATION

Dried seaweed web (the web is tan to orange-brown in colour) is cut up to small pieces and soaked in water overnight. This mixture is then cooked in a pan over low heat until the seaweed is dissolved, but do not boil. After cooling the non-gelling solution is strained through a Japanese silk strainer, a cotton cloth or nylon stockings to remove undissolved residue. The solution will be light drab tan in colour and feel "slimy". It is best worked when warm and can be applied with a brush.[79] Low concentrations can also be used with an ultrasonic mister.

JUNFUNORI

GENERAL INFORMATION

JunFunori is a polysaccharide complex obtained from Funori which was developed quite recently and is solely supplied by Lascaux Colours & Restauro. It is hydrophilic, therefore it is soluble in water and can slowly absorb it.[80]

Because of the production process of Funori the quality of the product can vary, having an influence on the colour and ageing characteristics. To counter the disadvantages of the traditional natural product Funori, a cleaning process was developed in a follow-up project at the Swiss Federal Laboratories for Materials Testing and Research (Empa) and a new consolidant, extracted from red algae, was produced in the form of a white powder. The new, colourless product JunFunori (Jun = pure) has the same properties as Funori but the adhesive strength and viscosity is higher. [81]

In investigations into its long-term stability by Empa, JunFunori performed well during accelerated ageing considering its optical and tensile properties.[82] Further testing in the field by museums, conservators (predominantly in Switzerland) and the Berne University of the Arts also generated positive feedback.[83]

[79] http://aic.standford.edu/sg/bpg/annual/v03/bp03-05.html
[80] http://aic.standford.edu/sg/bpg/annual/v03/bp03-05.html
[81] Nideröst (2002), p. 28
[82] Nideröst (2002), p. 29
[83] Nideröst (2002), p. 29

PREPARATION

JunFunori was developed with the conservation of matte paint in mind.[84] Usually low percentage aqueous solutions of JunFunori are prepared for consolidation, higher ones are very viscous. Therefore, a certain amount of JunFunori is dissolved in distilled water under intensive stirring or shaking, ideally at 40°C.

It has to be warm during application which can be done by brush. For ultrasonic misting the concentration should be around 0.5% because of the viscosity.

SODIUM ALGINATE

GENERAL INFORMATION[85]

Like Funori sodium alginate is an algae derived product. This sodium salt ($NaC_6H_7O_6$) of alginic acid is extracted from the cell walls of brown algae *laminaria hyperborea* and comes in an off-white powdery form. Its industrial use is as emulsifier, thickener and to increase viscosity, in paper conservation it is used as adhesive, consolidant and fixative in much the same way as Funori.

Soluble in water and amylase enzymes its dried film is very matte and flexible, has a low viscosity and is reported to being able to be applied repeatedly without altering pigments and substrate.

PREPARATION

Sodium alginate needs to be soaked slowly in warm water until it dissolves and can be lumpy until it does. Solutions are made best by dissolving it with a magnetic stirrer. Although it does not gel solidly when cold it is best applied warm with a brush.

[84] Brown (2002), Swider/Smith (2005), Grantham (2002), Geiger/Michel (2005)

[85] Conservation Department University of Northumbria: Survey of fixatives and consolidants commonly used in paper conservation / Food and Agriculture Organization of the United Nations FAO: Corporate Document Repository, webpage

METHOCEL A4C

GENERAL INFORMATION[86]

Methocel A4C is a methyl hydroxyl propyl cellulose belonging to the group of cellulose ethers. The A4C type contains 85-99% methyl cellulose, water and sodium chloride.[87] It is one of the most used types in paper and paintings conservation as consolidant and adhesive.

This type of Methocel has the best solubility in water and as a non-ionic cellulose ether it is not prone to form complexes or insoluble precipitation with metal salts or other ions.

PREPARATION

Methocel comes as an off-white powder that has to be dissolved in water. The best way to is putting the measured amount of water on a magnetic stirrer and adding the Methocel slowly under high stirring, since it otherwise has the tendency to go lumpy. Slight warming of the water helps dissolving the powder a bit faster than in cold water. The dissolution takes a while, so it is best prepared the day before use.

BLANOSE 7M8SF

GENERAL INFORMATION

Blanose Refined CMC is the sodium salt of carboxy methyl cellulose, which has been purified to a CMC content of 98 % minimum, belongs to the group of cellulose ethers, which are used in conservation for consolidation, adhesives and facings.[88]

Carboxy methyl cellulose as tested by Feller[89] seems to have very good stability with respect to weight loss, photo stability and discolouration. Horie[90] mentions that CMC might cross-link with

[86] Feller (1990), p. 58

[87] Conservation & Art Material Enyclopedia Online, Museum of Fine Arts Boston, http://cameo.mfa.org/materials/record.asp?key=2170&subkey=5968&Search=Search&MaterialName=methocel

[88] Feller (1990), p.95

polyvalent ions, possibly creating solubility issues. With increase in moisture it is said to become more flexible, which would be a very useful property.
The CMC used in Feller's tests was Cellulose Gum, which has since been renamed by Aqualon (Hercules) to Blanose. One of the low viscosity CMCs (Cellulose Gum 9M8, viscosity 400-800 mPa.s. (2%)) has its closest relation in viscosity and other properties in Blanose 7M8SF (viscosity 200-800 mPa.s. (2%)), which is the one chosen for this testing.[91]

PREPARATION
Blanose comes as an off-white grainy powder that has to be dissolved, in this case in water. The best way to achieve this is to put the measured amount of water on a magnetic stirrer and add the Blanose slowly under high stirring, since it otherwise has the tendency to go lumpy. The dissolution takes a while, so it is best prepared the day before use.

KLUCEL

GENERAL INFORMATION[92]

Klucel is a hydroxy propyl cellulose, belonging to the group of cellulose ethers. Although Klucel has the same ageing qualities as methyl cellulose or CMC, it is regarded as less thermally stable. Testing by Feller has shown extensive weight loss and discolouration at 90°C, which would be of less concern in the rather cool conditions it would be used here. [93] A point to be considered is possible acid hydrolysis, since the paint layers tend to be slightly acidic.

All Klucel types are soluble in water and many polar solvents like ethanol and acetone.[94] Since the lower viscosity classes are more stable, the types E and G are most used in conservation since

[89] Feller (1990), p.95
[90] Horie (1995), p.129
[91] oral information Philip Bale, Aqualon (Hercules UK) - 2007
[92] Lascaux Data Sheet, www.lascaux.ch/english/restauro/pdf/7152_02_a.pdf
[93] Feller (1990), p. 94
[94] Emberger et al. (2002), p.192

the early 1980s.

PREPARATION
Klucel comes as white powder that has to be dissolved, in this case in deionised water. The best way to achieve this is to warm a measured amount of water on a magnetic stirrer and add the Klucel slowly under high stirring, since it otherwise has the tendency to go lumpy. The water should not be over 38°C, otherwise the Klucel will precipitate out of solution. The dissolution takes a while, so it is best prepared the day before use.

TYLOSE MH300

GENERAL INFORMATION[95]
Tylose MH300 is a methyl hydroxyl ethyl cellulose belonging to the group of cellulose ethers. It comes as a white powder and is one of the low viscosity Tyloses. Different types of Tylose are used in conservation as adhesives and consolidants for different materials.

MH types are soluble in water, but to a different extent. The more highly ethered MHB types can also be dissolved in chlorinated hydrocarbons and alcohols and mixtures thereof.

PREPARATION
The MH 300 type of Tylose has the tendency to clump in cold water, so it is advisable to warm the water and add the powder slowly under stirring on a magnetic stirrer. The stirring needs to be kept up for at least half an hour while the solution is kept warm until the Tylose is totally dispersed.
Since Tylose, as well as most other cellulose ethers, tends to become quite viscous with rising concentrations, low concentrations are most useful.

[95] Lascaux Data Sheet, www.lascaux.ch/english/restauro/pdf/7151_02.pdf

PARALOID B72

GENERAL INFORMATION[96]

Paraloid B72 is a methyl / ethyl methacrylate co-polymer (also known as Acryloid B72) which comes in granules which can be dissolved in acetone or aromatic solvents like toluene or xylene. It is less soluble in isopropanol, ethanol and methoxypropanol.

Paraloid B 72 has been used since the 1950s in conservation as a consolidation agent and as a picture varnish. Extended tests have shown it to be one of the most stable resins used in the conservation of works of art, although sometimes it is claimed to cross-link.[97]

It is used to consolidate and impregnate mural paintings and oil paintings, as a fixative for charcoal and chalk drawings, pastels, as well as for the consolidation of wood.

It is also recommended as an adhesive for glass and ceramics.

When working with Paraloid B 72, the right thinning rate is decisive for a successful treatment. Tests have to be made in order to determine the thinning rate and the appropriate solvent to provide good penetration and consolidation properties. Since objects show different absorptions, it is advisable to work with lower concentrations. There is a risk of undesired saturation on the surface of the object when working with too high concentrations.

The solvent retention must be taken into consideration, especially when using solvents with a low evaporation rate. It may take days or weeks for complete evaporation of the solvent. The result of the consolidation can be judged only after complete drying of the resin.

Excess resin or gloss can be removed with acetone or toluene.

PREPARATION

For the conservation and consolidation of ground and pigment layers on wood or canvas supports, a 5 - 10% solution in toluene or toluene/isopropanol is to be used. Since it has a good penetration, higher concentrations might have to be tried to successfully adhere a tissue to the paint surface.

Paraloid B72 is best dissolved with a magnetic stirrer.

[96] Lascaux Data Sheet, www.lascaux.ch/english/restauro/pdf/7103_02.pdf

[97] Bentley (1998), p.39

LASCAUX 360HV

GENERAL INFORMATION[98]

Lascaux 360HV is a dispersion of a thermoplastic acrylic polymer on the basis of methyl methacrylate and butyl acrylate, thickened with acrylic butyl ester. It is generally used as a cold and warm lining adhesive, but its tackiness at room temperature (Tg –8°C) makes it also very suitable as contact adhesive for other conservation treatments.

Apart from its permanent tackiness it is also very elastic, which could be an asset in the use as facing adhesive. Further properties as stated by Lascaux are age-resistance and cross-linking resistance. Although Lascaux 360HV is thinnable in water, once it dries it only stays soluble in alcohol, acetone, toluene, xylene and Thinner X and stays insoluble in non-polar solvents like White Spirit.

PREPARATION

For use as a facing it is best to apply the Lascaux 360HV to the tissue and leave it to dry, before it is applied carefully to the surface. With thin tissues, the adhesive will also penetrate to the other side, so letting the tissue dry free hanging is best or on a silicone coated melinex sheet.

AQUAZOL 50/200/500 (Poly-2-ethyl-2-oxazoline)

GENERAL INFORMATION

Aquazol or poly-2-ethyl-oxazoline (C_5H_9NO) has found its way into conservation in the 1990s from industrial use as substitute for PVOH and PVP in high temperature applications in a variety of hot-melt and pressure sensitive adhesive products since 1977.[99]

[98] Lascaux Data Sheet, www.lascaux.ch/english/restauro/pdf/7050_02und7051_02.pdf

For conservation it comes as a light yellow granular solid in three different molecular weights (50=50,000 / 200= 200,000 / 500=500,000) and is solely supplied by Polymer Chemistry Innovations Inc. (PCI) in the US. It is specifically used as an adhesive, infill binder and in-painting medium, its glass transition temperature of 55°C makes it also useable as a heat-seal adhesive.[100]

In solution Aquazol tends to be neutral and it is soluble in many polar, organic solvents such as water, alcohol, acetone, dimethyl formamide, methylene chloride and methyl ethyl ketone. Though stable in weak acids and bases, the amide group hydrolyses in strong acids and bases.[101]
Wolbers and Arslanoglu have done extensive testing to evaluate its application as a consolidant and ageing characteristics. Wolbers found Aquazol to be hardly light ageing, continuously plastic and soluble in the same solvents, but seemingly sensitive to high RH since it is highly hygroscopic. As the best in case studies revealed the Aquazol 500 in water mixed with some IMS for better penetration.
Arslanoglu validated these findings and additionally tested for drying shrinkage, which she found to be neglectable and mould growth, which was non-existent.[102]

PREPARATION
The yellowish granules can be dissolved cold in the appropriate solvent. Generally Aquazol dissolves better in acetone than water or alcohol.
The length of the dissolution varies, with a magnetic stirrer Aquazol can dissolve in a few hours, without it takes over night. The higher the molecular type, the longer it takes as well.

[99] Wolbers (1998), p. 514
[100] Wolbers (1998), p. 515 / Arslanoglu (2003 / Vol. 25), p. 12
[101] Wolbers (1998), p. 515
[102] Arslanoglu (2003 / Vol.25), p. 13, 15

LASCAUX MEDIUM FOR CONSOLIDATION

GENERAL INFORMATION[103]

Lascaux Medium is a finely dispersed, aqueous dispersion of an acrylic copolymer, containing various additives (~3%) and solvents (~2%). The Medium for Consolidation has been developed by Lascaux Colours & Restauro in cooperation with the Swedish National Heritage Board for the consolidation of matte paint layers in medieval polychromy on wood to replace Acronal 300D by BASF, which had been terminated.

As a liquid it is thinnable with water, but once it has dried, it only remains soluble in esters, aromatics, acetone and ethyl methyl ketone. The formed film is clear and flexible and according to extensive testing light and age resistant.

The Medium for Consolidation has excellent penetrating power due to is low viscosity. This allows for the safe and efficient consolidation of loose and chalking paint layers, even on water sensitive surfaces such as gilding or thin layers of size-tempera. These can be consolidated without swelling or spotting on wooden or textile supports. A concern in some cases might be the pH of approximately 8.5.

Excess medium of consolidation can be removed completely with acetone or xylene after a drying time of approximately 24 hours.

The Medium for Consolidation has been successfully used on various objects in numerous Swedish restoration studios. According to the manufacturer Lascaux Medium for Consolidation is physiologically and toxicologically safe in conventional usage.

PREPARATION

Lascaux Medium for Consolidation comes ready to use and can be brushed on straight away.

Undesired sediments, which might appear during storage, can be strained with a filter before application. The concentration of it can be adjusted by addition of distilled water. Prior to application of consolidant white spirit can be used as wetting agent.

[103] Hedlund, Johansson (2005), pp. 432-439

BEVA 371 (BERGER ETHYLENE VINYL ACETATE)

GENERAL INFORMATION[104]

BEVA is a heat seal adhesive that was developed by Gustav A. Berger and is predominantly used for lining paintings, facings and laminates. It is a mixture of ethylene-vinyl copolymers and hydrocarbon resins in petroleum solvents of about 55% aromatic content, the solid contents is approximately 40%. Its activation temperature is about 65-70° C. At 65°C BEVA becomes as tacky as a contact adhesive at room temperature. A firm bond can be achieved almost instantly and with minimal pressure so that even the most delicate textures do not suffer.

It can be used with heat only and/or non-polar petroleum factions. Since it is non-aqueous and known to be harmless to most paint films it can also be used to consolidate water-sensitive paint. In set form it causes no contractions, expansion or softening of the materials to which it is applied. Shrinking and distortion is minimal. BEVA can be applied by brush, paint roller or spray without impregnation of solvents. It is possible to lower the heat sealing temperature by using BEVA films half dry or moistened with sprayed on petroleum fractions.

PREPARATION

BEVA can be applied as a facing adhesive by brushing the heated adhesive straight through the tissue, but to have thinner concentrations it can be diluted under warming to about 30% with Stoddard Solvent, which seemed to be the ideal concentration for this kind of facing. The warm mixture can be applied by brush through the tissue. To create a secure bond throughout the facing the wetted tissue needs to sit undisturbed until the solvent has completely evaporated. Otherwise parts of the tissue might not adhere properly.

[104] Talas Data Sheet, www.talasonline.com/photos/msds/Beva_371_solution.pdf

MOWILITH DMC2

GENERAL INFORMATION[105]

Mowilith DMC2 is a 55% aqueous dispersion of the Mowilith product group of polyvinyl acetates, a copolymer of vinyl acetate and maleic acid dibutyl ester with a glass transition temperature of 10°C. The Mowilith range is used predominantly in textile and painting conservation for consolidation and repairing tears in canvas and supplied by Lascaux Colours and Restauro.

It is a flexible, thermoplastic polymer with high transparency. Lascaux and Down[106] certify excellent light fastness, but tests by Howells[107] showed yellowing. It remains to be seen, how the adhesive reacts to the proposed ageing sequence. Solubility is given in ethanol + 5% water, ethyl acetate, butyl acetate, acetone, methyl ethyl ketone, methyl isobutyl ketone and toluene; to a limited extent soluble in ethanol and xylene. Mowilith DMC2 can be further diluted with water, but once dry it is insoluble in water, cyclohexane, special boiling point gasoline (80/110) and diethyl ether.

PREPARATION

Mowilith DMC2 opaque white dispersion comes ready made, but very viscous. For a facing adhesive it needs to be thinned down. Solutions of less than 20% tend not to be sufficiently sticky any more. The thinned solution can be brushed on cold.

[105] Lascaux Data Sheet, www.lascaux.ch/english/restauro/pdf/7106_02.pdf
[106] Down *et al*. (1996), p. 38
[107] Howells *et al*. (1984), p. 38

CYCLODODECANE

GENERAL INFORMATION

Cyclododecane belongs to the class of non-polar, saturated, alicyclic hydrocarbons and comes as a clear, crystalline substance. Because of its molecular structure and high vapour pressure it is a wax-like solid at room temperature, but will start sublimating slowly when exposed to air. Sublimation means the instant transition of a material from solid to a gaseous state.[108]

It is manufactured synthetically and is used industrially for the production of synthetic fibres.
In its reactivity it can be compared to the saturated, aliphatic hydrocarbons, being even less reactive, and is one of the most stable alicyclic hydrocarbons (thermal stability even at 400°C).[109]
Cyclododecane is highly soluble in non-polar solvents like pentane, hexane, isooctane, octane, naphtha and dichloromethane, but almost insoluble in polar solvents like water, ethanol, isopropanol or acetone. This insolubility in polar systems has made it ideal as a protection for water-sensitive surfaces during conservation. Most importantly cyclododecane is non-toxic and environmentally safe.[110]

Since cyclododecane disintegrates in two phases from a hot liquid melt, it behaves differently on non-absorbent and absorbent surfaces. The latter is the important factor for this research, because the size-tempera paint layer is very absorbent unless wax-treated. When the melt is applied on an absorbent surface, the cooling process separates a fluid phase from the solidifying one, which will be absorbed, leaving a dense, wax-like film on the surface. This film is pressure and abrasion resistant.[111]
The presence of both phases on a non-absorbent surface will cause the cyclododecane to form a brittle layer of crystal needles, which is very vulnerable to pressure and abrasion.[112]

[108] Geller, Hiby (2002), p.14
[109] Geller, Hiby (2002), p.14
[110] Hangleiter, (1998), p. 316
[111] Hangleiter, (1998), p. 316
[112] Hangleiter (2008), webpage

Depending on the thickness of the dense film, the temperature and airflow, the sublimation can take a long time. It is possible to speed it up by applying a hot air gun or solvents.[113]

PREPARATION

Cyclododecane can be applied as a melt, dissolved and both as spray. Each technique changes the appearance of the crystalline layer and depth of penetration. A layer cast from a straight melt will have the most solid layer and will hardly penetrate.

A melt can be applied by brush, which needs training to apply it correctly, or with a heated spray gun. The application by brush has to be executed quickly, because the cyclododecane solidifies nearly instantly when touching the surface. This will form a dense but uneven layer, which can be evened out with a heated spatula or a lamp with high IR radiation. A wide synthetic brush works well.

The adhesive can be dissolved in a range of non-polar solvents, which makes the application by brush easier, but the penetration also deeper. The layer will be less solid than one formed from a melt. Repeated application to build up the layer is not very successful. Geller and Hiby give a list of possible solvents and solvent mixtures that have been tested on chalk grounds.[114] The most appropriate that shows the least influence on the chalk ground is an un-saturated mix of cyclododecane, isopropanol and petrol ether 30-40 (10g +30g+7g). The best way seems to be to mix the liquids together first and add the cyclododecane afterwards, dissolving it with a little heat. Precipitation of the cyclododecane within the cold solution might occur (as in photograph).

To apply cyclododecane as spray either as melt or dissolved, a heated spray gun is needed.

MENTHOL (Menthanol-3 / 1-methyl-4-isopropyl-cyclohexanol-(3))

GENERAL INFORMATION[115]

Like the cyclododecane menthol is a volatile adhesive that behaves similar as well. A major component of the peppermint, menthol is a terpen, that can also be produced synthetically, then building long lance-like crystals. An example for its industrial use is as part of an acaridical composition in resin mouldings used for beddings.[116]

[113] Hangleiter (2008), webpage
[114] Geller, Hiby (2002), p. 117
[115] Hangleiter (2008), webpage

Because of the secondary OH-group at the C-3 the molecule can be acid-sensitive under certain conditions, for it can form double bonds when splitting off water. Considering the slightly acidic nature of the paint layers and the plain wood, this could lead to complications with sublimation. Its melting point is about half as high as that of cyclododecane, making it easier to work with, but the film formation takes longer and often goes from the edge inwards. From a melt the film solidifies similarly to cyclododecane, but is not as homogenous. It has a more crystalline, semi-opaque appearance comparable to iced over windowpanes, forming adjoining crystal circles. The surface of the film stays lightly sticky.
Menthol is soluble in most usual polar and non-polar solvents apart from water, which can only be changed by using a 50:50 mixture of ethanol and water.
The properties of the film are very similar to cyclododecane, except that it sublimates more slowly. It will only protect the surface from water, but no other solvent. The low melting point makes removal with a hot air gun quite easy.

PREPARATION
Menthol has excellent usage as a melt, because it does not tend to solidify in the brush before being applied to a surface. A melt is prepared by heating the crystals in a water-bath above 50°C to improve workability. The higher the temperature of the melt, the higher its penetration.
Since menthol can be dissolved in a wide variety of solvents, solvent-based application is a possibility. A fast cooling transition past the melting point will result in a more homogenous and denser film, thus selecting a highly volatile solvent with a low melting point will create the densest film possible.

3.2 FACING MATERIALS

To determine a range of usable facing tissues different tissues were used with gelatine as a single adhesive. Gelatine has relatively low viscosity and high reference value.

Eltoline is a thin, lightweight, non-buffered tissue, made from 100% long fibred manila fibres. It comes with good wet strength properties is sulphur-free and has a pH 6.0. It can be purchased

[116] Suita, et al. (1994), webpage

both in sheets or rolls; here eltoline on a roll is used. Despite those recommendable properties, the conservators at NIKU[117] consider it inferior to Japanese kozo tissue for facings and consolidation.

Two machine made and a hand-made Japanese kozo tissue, K-51N, represent the Japanese tissues that are widely used for conservation purposes because of their good properties.[118] Japanese tissues can be thin, but still very strong, wet and dry, and acid-free. These tissues come in a variety of mulberry fibres; kozo, gampi, mitsumate and their mixes; and the properties vary accordingly. Both the roll tissue and the hand-made one from PaperNao are pure kozo fibres, the so-called 'mulberry' tissue roll supplied by Conservation Equipment, (330512047), has no specific information about which mulberry fibres were used to make it. Pure kozo tissue has the best qualities for use in conservation that result partly from its long fibres. Mostly hand-made tissues are in use but considering the needed quantities and the prices, an economic compromise are the machine-made varieties. A difference to the hand-made one to consider is that, because of the manufacturing process, fibres in the machine-made one have a tendency for an alignment along the length of the roll. This causes slight differences in flexibility across width and length.
The three tissues have a comparable thickness, but the 'mulberry' tissue differs by having on side smoother than the other.

To see, whether a thick tissue might yield a better protection, especially considering transport, a thick, fibrous mulberry tissue (non-Japanese) was chosen. The acid-free tissue comes in sheets and in its natural light brown colour.

The last tissue to have been chosen is the synthetic non-woven Hollytex, which is extensively used for interleaving and support in paper conservation.[119] It is made from 100% polyester and is solvent and tear resistant.[120] From the two available thicknesses the thinner one seemed the more promising one, considering it needs to mould itself well to a surface.

[117] oral information Barbro Wedvik - 2007
[118] recommendation Linda Ramsay and Saho Arakawa, National Archives of Scotland – 2007 / New (2003)
[119] oral information Prof Elke Mentzel, Berne University of the Arts - 2004
[120] Lascaux Data Sheet, www. Lascaux.ch/English/restauro/pdf/7351_02.pdf

4. PRELIMINARY TESTING

4.1 FACING MATERIALS AND ADHESIVES

Preliminary testing was carried out on left-over fragments from original painted ceilings and divided in special subdivisions; facing adhesives, facing tissues, and consolidants.
These were used to narrow down the choice of applicable adhesives and concentrations. Conservators at the Hamilton Kerr Institute[121] and in Germany have used a brush and syringe to apply adhesive directly underneath loose flakes for consolidation, but this method is very time consuming and works best with bigger solid flakes, not powdery fragile paint on a bigger scale. The method used by Historic Scotland and the National Trust for Scotland is also used successfully in Norway and Switzerland.[122]
A facing method is to use adhesives of higher concentrations. This keeps the penetration rate as low as possible, as the facing adhesive is generally not the consolidation adhesive. Thick facing adhesives also have to be removed more forcefully and this could lead to mechanical damage to the paint layer. It also needs to be considered that they could leave non-removable glossy patches, therefore they seem not to be appropriate. Thus, it was decided to use consolidation concentrations that will penetrate more and, instead of only giving surface protection, will act as a consolidant that anchors the paint flakes from below while the facing is taken off. Secondly, no intense mechanical actions is needed for removal, just re-dissolving the thin surface layer should suffice.

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4.1.1 Preliminary Testing Adhesives

A selection of adhesives has been made after the preceding research of those that might be suitable. The details and close up photographs for the preliminary adhesive testing can be found on the Appendix CD.
To get an idea which adhesive concentration would work best for the task at hand, several consolidation strength concentrations for each adhesive were mixed and applied through squares of Eltoline to evaluate its gloss at the given concentration (illus. 7).[123]

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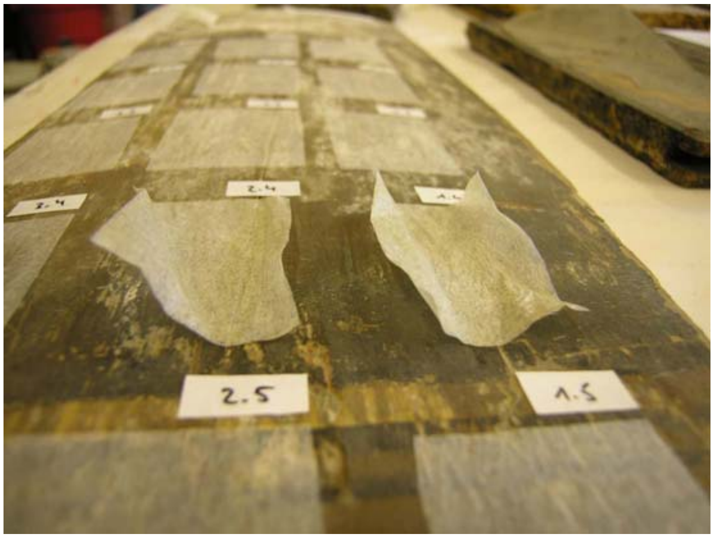
[121] Marie Louise Sauerberg, Hamilton Kerr Institute Cambridge; Talk at the ICON conference on Polychrome Wood 26/10/2007
[122] NIKU Oslo, Berne University of the Arts
[123] detailed information on the testing can be found in the Excel file 'Facings' on the Appendix CD

Some adhesives showed saturation of the paint layer, but synthetic adhesives mainly showed gloss in higher concentrations (which were then scaled down). For some like the Paraloid, Lascaux Medium, Mowilith and BEVA this did not work because they lost too much adhesion. For Klucel E the initial concentration had to be increased to provide more adhesion, too. Concentrations higher than 2% were problematic for the cellulose ethers, which became too viscous to penetrate the tissue properly.

Illus. 7 Original panels with preliminary facing and consolidation trials

The sodium alginate was found to be totally unsuitable for a facing because through drying shrinkage the tissue crinkled extensively and lifted off almost completely (illus. 8).



Illus. 8 For both sodium alginate facings the tissue has lifted away from the paint surface during drying, making this adhesive unsuitable

Generally it can be said that sodium alginate, Lascaux 360HV and Paraloid B72 could be ruled out. Sodium alginate had too much drying shrinkage, 360HV as a contact adhesive was inefficient and B72 could not be applied though tissue in low concentrations, has low tack due to deep penetration and a reputation[124] as a damaging humidity barrier. Though found to be reversible on a 37 year old facing, there appeared problems that are described in detail below.

It has become very obvious, that most higher concentrations of adhesives other than protein glues will produce gloss, so they would have to be used in low concentrations. The promising ones were retained for tensile testing, sometimes in two or three working concentrations.

During the consolidation trials (illus. 7 bottom) direct comparisons were not always successful, because the testing panel had a paint layer of different thickness and dust accretions and varying degrees of exposed wood. Naturally exposed and dusty wood would become darker and more lustrous after the application of a consolidant, whereas on a light size-tempera paint layer the result looks different. This is why it was decided to use the standardised panels parallel in the testing sequence.

[124] For example it was seemingly responsible for extensive mould growth after the conservation of the imperial coffin in Tokyo

Pressure Sensitive Adhesive Lascaux 360HV

It was thought initially that a contact adhesive might be an option, but looking at the performance of Lascaux 360HV acrylic adhesive, it was ruled out.[125] The application was tricky on thin tissues because of penetration to the other side and thick tissues did not conform well to the surface with a contact adhesive (Appendix CD). The slight tackiness that remained after drying was enough to adhere the tissue, but with thin tissues the tack was on both sides. Removal was the major setback with this adhesive (illus 9). If it is removed like ordinary tape, it takes with it a lot of loose paint flakes. Wet removal with Industrial Methylated Spirit (IMS) worked slightly better in terms of removing less flakes, although it was very difficult to get right. The amount of rubbing and swabbing through the tissue often tore it apart and if the IMS evaporated during the process, it left a mess of sticky adhesive and torn tissue behind that was nearly impossible to remove without damaging the paint layer.

Illus. 9 Lascaux 360HV facing trials after removing them halfway

[125] detailed information on the testing can be found in the Excel file 'Facings' on the Appendix CD

Removal of an aged Paraloid B72 facing

An old facing trial was found from about 37 years ago with Paraloid B67 / B72 and something called B10, which is thought to be a PVAc. Initial part removal of the B72 with acetone revealed continued solubility, but also the need for post-cleaning, since it left glossy residues on the surface. After the cleaning micro-cracks became visible, which are possibly the result of the use of acetone to dissolve the B72 (illus. 10). It did not happen with toluene but significant mechanical action is still needed to get the facing off. Further post-cleaning would be even more damaging.

Illus. 10 Close-up of the paint surface after B72 facing removal with acetone. The black outlines of the grapes show a network of micro-cracks.

4.1.2 Preliminary Testing Facing Tissues

Tissues were tested with gelatine in order to determine how far different types and thickness could be beneficial to a facing on such a friable surface (illus. 11).[126] No property testing was done, since it has been done numerous times and certain tissues, like Japanese ones are quite well established in conservation. Mostly the choice among those is a personal one and influenced by the surface the facing has to be applied to. The choices here were mainly taken with the advice of paper conservators at the University of Northumbria and the National Archives of Scotland.

Illus. 11 Original test panel with facing tissues, adhered with gelatine

Of the tissues tested as facing material, the thicker ones seemed not to be ideal since penetration is low and surface conformation unsatisfactory. Thin tissues, Eltoline and Japanese mulberry (kozo) tissues seem to be the most promising. One of the kozo rolls however is unexpectedly unpenetrable to adhesives on one side. Hollytex did not work well with the protein glue. It might be better used in conjunction with thick adhesives, especially synthetic ones. The protein glue could not uniformly adhere the paper to the surface.

[126] detailed information on the testing can be found in the Excel file 'Facings' on the Appendix CD

4.1.3 Volatile Adhesives

A good method of applying the volatile adhesives is by spraying them on. Since cyclododecane in a spray can had a very high pressure, effectively displacing paint flakes, an alternative method was to use an adjustable heated spray-gun. A viable solution for converting a regular spray-gun to a heated one was given by Dr. Elisabeth Jägers in Germany.[127] She had a big part in testing these adhesives and knew the conservators who work with them, too. Her recommendation was band heaters for the spray cup.

Illus. 12 Converted spray gun for cyclododecane

After looking at different products it was decided to use a silicon-heating sheet of appropriate dimensions to wrap the cup, using it with a percentage controller (illus. 12). The sheet could be wrapped around the cup and the right percentage for the temperature determined with a thermometer in the cup filled with water. 25% energy was needed to heat the cup to the cyclododecane's melting point of about 70°C without spreading the heat to the metal gun. The plastic cup was stable at that temperature. It has been tested for heat stability beforehand.

During trials using cyclododecane, the spray-gun turned out to be unsatisfactory. The heated pad around the cup kept the cyclododecane melt in a liquid state, but the metal of the spray gun stayed cold. As a consequence the cyclododecane solidified in the gun, effectively blocking it. Although the spray appeared to be very thin it included some big drops that were hurled from the tip of the gun.

Another application form was tried, this time with the cyclododecane in a solvent mixture as described by Geller und Hiby[128] as suitable for chalk ground; cyclododecane / isopropanol / petrol ether 30-40 (10g/2g/7g). It was hoped that the solvent would delay or eliminate the continued blockage. After several trials this also had to be abandoned for the same problems as before.

[127] oral information Dr Elisabeth Jägers, Vice Dean of the Institute for Conservation Science Cologne - 2007

[128] Geller, Hiby (2002), p. 117

Effectively, it was not possible to incorporate sprayed applications of volatile adhesives into this research project. However, it is definitely an application method that should at some point be tried with the right equipment, as spraying covers wide surfaces fast without the need to touch the paint layer and the layer will be very even. Hangleiter had spraying equipment specially modified to get a high temperature and have all the necessary parts of the spray fully heated.[129]
The influence of the airflow on the loose flakes would need to be addressed, as increased airflow might displace paint flakes.

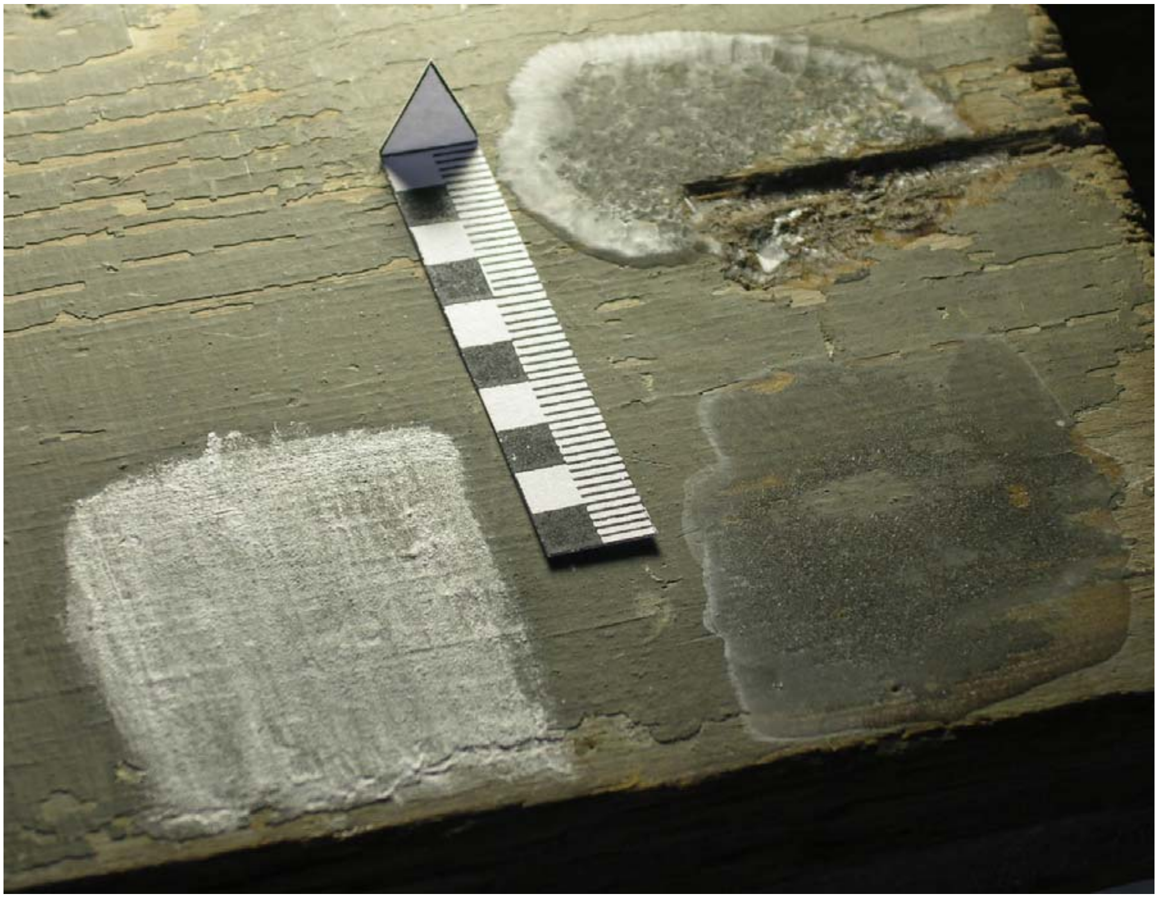
Another method was to apply the cyclododecane onto some tissue, take it to the paint surface and apply it by re-liquifecation. The drawback of this method was the application of the cyclododecane to the tissue. Unfortunately instant solidification left the tissue very uneven and transferring the adhesive with a heat spatula to the paint would displace or crush loose flakes. Transfer from melinex had the same problem. Transport of the cyclododecane-coated sheets would also have been a difficulty, since the film broke easily and flaked like a thin wax layer does.

The only application method left for the testing was by brush, which for treatment might prove unsuitable, if the paint layer is flaking badly.
Both cyclododecane and menthol were applied with a brush as a melt (from a jar on a hotplate). The hot melt yielded a much more solid wax-like film, because the crystals forming it packed tighter than those formed from a solvent state. With the solvent the film became a layer of thin, powdery consistency. This film would be useful only for *in situ* facings, not for any kind of transport.

During this testing it was found that both adhesives work well as a melt (illus. 13). When hot enough, they flowed rapidly from the brush and solidify soon after. Even with the brush barely touching the surface, tenting flakes could be underlaid and surrounded with the adhesive very quickly. Since menthol took longer to solidify, this technique was not as successful as with the cyclododecane. The menthol also took much longer to sublimate. [130]

[129] Hangleiter (2008), www.cyclododecane.net/html_e/index_.htm. Hot-speaying machine by the company Wilhelm Wagner (WiWa), modified by Eltherm. Boiler, pump, tube and spray-gun heated, temperature adjustable to 120°C, nozzle temperature should be at least 80°C and consumption at least 300g/m^2

[130] Sublimation is a material's process of instant transition from solid state of aggregation to gaseous. Because of the high vapour pressures of such materials, there is no liquid state in between the two. Sublimation for cyclododecane and menthol works fastest at room temperature, in colder surroundings it takes longer.

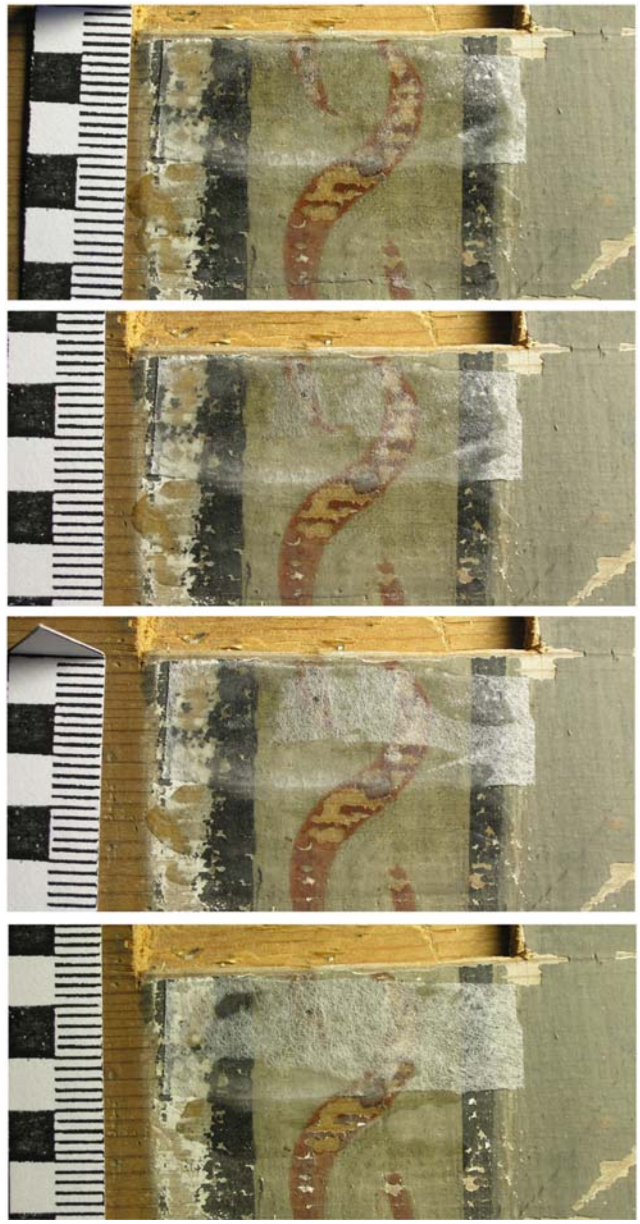


Illus. 13 Test application of volatile adhesives. Top right menthol melt, bottom right cyclododecane melt and bottom left dissolved cyclododecane.

The dissolved cyclododecane felt more like applying solvent, with the possible danger of displacing loose flakes more easily but it penetrated much more. Solidification took even longer and the settled film was very thin and fragile, it also sublimated much faster. Trying to apply several layers after the solvent had evaporated only dissolved the settled cyclododecane again and created a mess by displacing half dissolved adhesive. After several trials the application worked better, but still not entirely convincingly.

By applying the adhesive as melt or dissolved an unevenness of the film is obtained, since the adhesive starts to solidify as soon as it touches the surface. This will also make the sublimation uneven - thinner areas sublimate faster than thicker ones leaving the paint underneath unprotected.

To see, whether the application of a tissue might reduce the sublimation time, half of the area was covered with eltoline tissue before the adhesives were applied (illus. 14). The addition of the tissue slowed the sublimation slightly and there was the additional advantage that the tissue stayed in place as long as there were some remnants of adhesive, whereas in the uncovered areas flakes that were not covered by the adhesives were again endangered.



Illus. 14 Cyclododecane layer with and without facing tissue: freshly applied, after 1,2 and 5 days

For the accelerated ageing tests cyclododecane was applied thickly as melt and dissolved, the menthol applied as melt. Half of each application area was covered by tissue. It is not totally imperative for the after ageing evaluation that by the end of the process the volatile adhesives are still there, since the whole point is that they are volatile. To enable the examination of the application areas for discolouration and residues of adhesives even after sublimation, they were marked out with chalk.

4.2 TENSILE TESTING

While testing the adhesives on fragments of painted ceilings for practical conservation purposes, it became evident, that it was difficult to determine a concentration's adhesive strength. The adhesives should have enough tack to adhere paint flakes and the tissue to the surface, but not put any more strain on the paint layer. This would happen, if the adhesive is less flexible than the paint layer or more brittle and of very strong adhesion.

Thus, an initial method was devised to determine the particular adhesive strength by adhering two strips of balsa wood with the respective adhesive and concentration. Balsa wood was chosen for its absorbent qualities, as it appeared to behave similarly to painted wooden surfaces. The strips were 1cm wide and 6cm long, the joined surface 1cm by 3cm.
It was then tried to snap the joints by holding the ends and pulling them apart vertically. This just gave subjective impressions, but was effective to get a better idea of working concentrations.

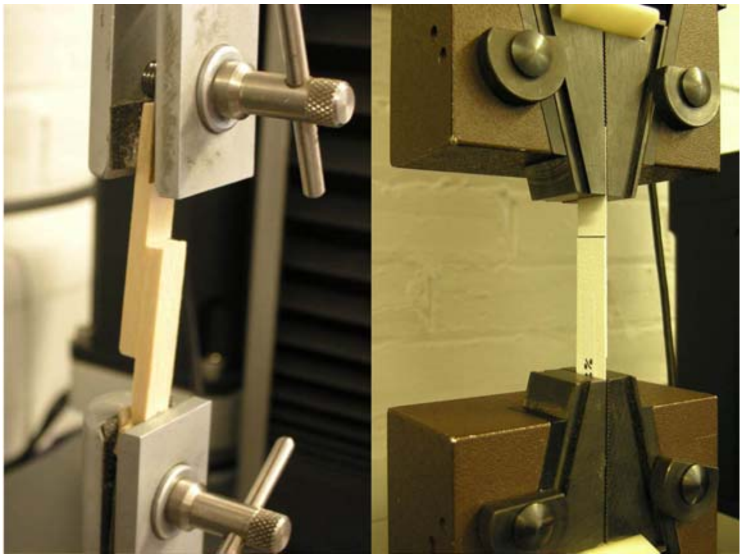
For those adhesives, which were deemed to be of suitable adhesive strength, a more precise method of tensile testing was chosen. Test samples are clamped into a material testing machine and pulled apart at a controlled speed to determine the shear strength. The shear strength is defined as the maximum shear force, which a material can withstand without breaking. This can be equated to an adhesive's strength and gives an indication whether the adhesive or material is going to give first. The tensile testing also indicates a material's brittleness or flexibility. Different parameters are recorded, in this case it seemed sensible to settle for F_{max} (maximal force in N), strain at max (in mm) and the Elastic Modulus E_{mod}. [131]

The stress-strain-diagram shows the tensile force that affects the cross section of the joint with parallel change of length. The linear part of the graph at the beginning shows the E_{mod}. At this point the tested material is elastic and the elongation is reversible. The steeper the linear part, the stiffer and less flexible the material is. After reaching the elastic limit, the graph becomes curved and less steep. This part shows a material's plastic interval, meaning the elongation becomes irreversible. Materials like adhesives or paint with a very small plastic interval are brittle and will break with small movements of the substrate. The end of the graph shows the breaking point.
The more brittle a material the higher the tensile force on the y-axis, the more flexible the higher the strain on the x-axis.

The maximal force in the output data describes the maximum of tensile force, and the strain at max. indicates how much a material is yielding to the applied maximum stress. To look at the

[131] N = newton (SI unit of force); a newton is the amount of force required to accelerate a body with a mass on one kilogram at a rate of one metre per second squared. $1N = kg \cdot m \cdot s^{-2}$. For example, on earth's surface, a body of 1kg exerts an average force of 9.8N on its support.

parameters at break seemed inconclusive, since the adhesive starts to give at F_{max}, F_{break} will always have a lower value and the break point could not be detected clearly by the machine for quite a number of the adhesives, thus giving no value at all. The E_{mod} defined as stress over strain and gives the value of a material's stiffness.



Illus. 15 Problematic balsa wood sample to be clamped in and paper sample with a different set of clamps

After experiencing problems with the balsa wood, several other woods (different stirring sticks, pine strip wood and a dark strip hardwood were tested in the same fashion, but with not much better results. Apart from very inconsistent data, the major issue was the alignment of the glued wood strips. They had to be inserted with spacers to fit the clamps, which resulted in increased slipping and the tension and torsion from the clamping often weakened the joint before testing, even snapping it during clamping since the clamps are not completely immobile.

To alleviate this, compression was tried. The wooden sample was fastened into the top clamp and driven against a metal plate, compressing the joint into failure. This method prevented pre-damaged samples, but created new difficulties, since any unevenness against the metal changed the readings. With nearly as many inconsistencies as with the other method, wood as a substrate had to be abandoned.

Even though paper has a different flexibility in itself than wood, it proved to be the best alternative, eliminating aligning problems and most inconsistencies (illus. 15). The latter now appeared to be confined mainly to the low concentration protein glues. This is probably due to the molecular structure and often creates difficulties in scientific testing.[132]

As test substrate, a 200g/m^2 watercolour paper was chosen. It has a reasonable strength; it spreads applied liquids evenly and works well for all water-bound adhesives. The dimensions of a sample

[132] oral information Craig Kennedy, head of conservation science Historic Scotland - 2008

were 7cm x 1.5mm x 0.3mm, those of the joint 3mm x 1.5mm x 0.6mm. The joint thickness is double the paper thickness, because the thickness of the dried adhesive layer could not be detected by calliper, apart from the BEVA films. Making evenly thick films from the adhesives proved not to be feasible for most of the adhesives.

The application thus was limited to brushing the adhesive on. For a uniform application on each sample identical brushes were used, the amount of glue limited to the brush's intake. After every use the brush was rinsed thoroughly and dried as much as possible on a paper towel. The error indicators in the results still vary, but even with repeated sets irregularities could not be eliminated for the low concentration protein glues, some concentrations of cellulose ethers and Aquazol, thus they have to be accepted.

The finished samples were placed between wooden panels and weighted to dry for a week before testing.

IMS (industrial methylated spirit), toluene, heptane, and white spirit penetrated too quickly through the paper to make the adhesive stick to the paper. Adhesives that had to be dissolved in one of these solvents therefore had to be exempted from tensile testing. This applied only to the Aquazol (which was tested dissolved in water anyway) and the BEVA 371.

The results for the water-bound versions supplied a reference, keeping in mind though that the increased penetration of the IMS would result in slightly less joint strength, as can be deduced from the facing tests. For getting an approximate guideline about the strength of BEVA, 20% in toluene were poured onto silicon coated melinex sheet and the dried film cut into strips. These strips could be ironed on, as well as BEVA 371 thin film by Lascaux.

Five samples for each adhesive in different concentrations were prepared to give an average for their respective tensile strength (adhesive strength). Testing was carried out by Napier University. As references the following materials were used:

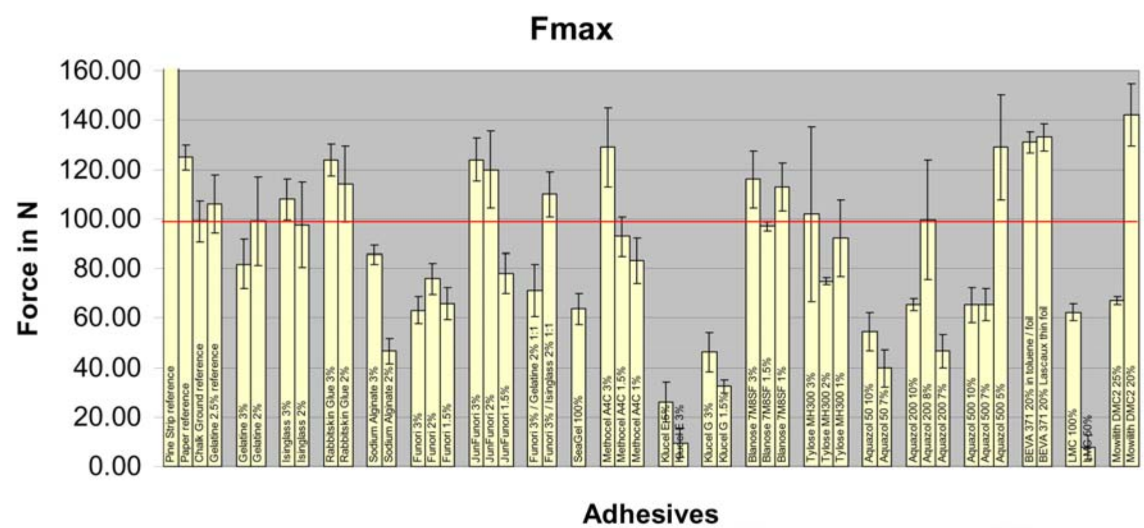
10. Strip Pine Wood (most ceilings are made of pine)
11. Plain paper with a test area as big as the joint (to eliminate the paper's own flexibility from the equation)
12. Chalk Ground (representing the paint layer / one layer of common gilders recipe with rabbitskin glue 2%)
13. Gelatine 2.5% (standard solution used on structural paintings at Historic Scotland)

The list on the Appendix CD gives the details of the test samples.

A Zwick/Roell ProLine Z050 TN material testing machine with 5kN clamps was used at a speed of 1mm/s.[133]

For the evaluation of the adhesives maximal force and strain, E_{mod} were compared. Some adhesives seemed to have increased or diminished the strength of the paper, thus giving an indication about their influence on a paint surface. The diagrams below show the adhesives' performance in all parameters in direct comparison.

In the diagrams the benchmark was provided by the chalk ground reference, representing the paint layer. Concerning tensile force (illus. 16) the range was quite widespread and without any visible groupings for adhesives of the same sort, like protein glues or cellulose ethers. Surprising was the low strength performance of Lascaux Medium for Consolidation, since it has been specifically designed for this kind of paint layer.



Illus. 16 Diagram for tensile strength. The red line indicates the strength displayed by the chalk ground reference.

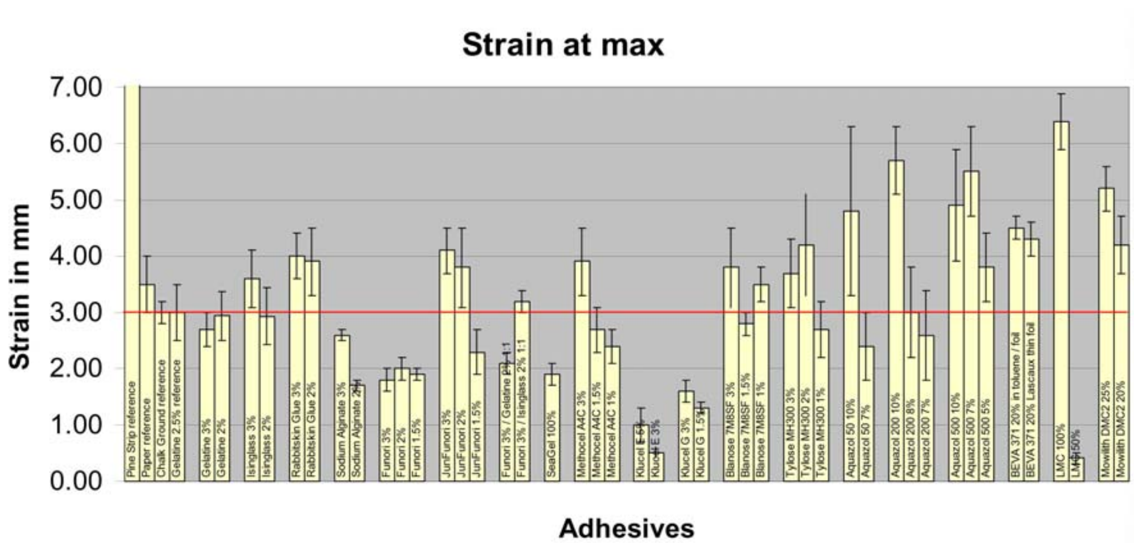
The protein glues have a tendency to be as strong as the paint layer. Exceptions are the gelatine 3% with less and rabbitskin glue with significantly more strength. SeaGel has much less strength than isinglass, although both are fish glues.
The algae glues on the other hand have more than 20N less tensile strength, which indicates that they would fail earlier than the paint layer. This can be a useful property, because the paint layer would not be actively damaged by adhesive resistance, but may lead to early failure in a humid

[133] The testing is done by Lynn Chalmers from the Materials and Manufacturing Research Group at Napier University, initiated by Alan Davidson. Details of the machine can be found on the Appendix CD.

climate. Interestingly enough the standardised Funori, JunFunori, surpasses its natural source in strength, which might result from the eradicated contaminations. The mixtures of Funori with gelatine and isinglass respectively behave very differently, although both are a mix of polypeptides and polysaccharides. The mix with gelatine has a reduced strength, while the one with isinglass is slightly stronger than the adhesives without Funori, for a reason not yet known.

Cellulose ethers seem to be dependent on their molecular compounds for strength. The least strong is the Klucel E, G (hydroxy propyl cellulose), then comes the Tylose MH300 (methyl hydroxy propyl cellulose) and Methocel A4C (methyl cellulose) and the strongest in general is the Blanose 7M8SF (carboxy methyl cellulose). The Methocel can vary very much in different concentrations.

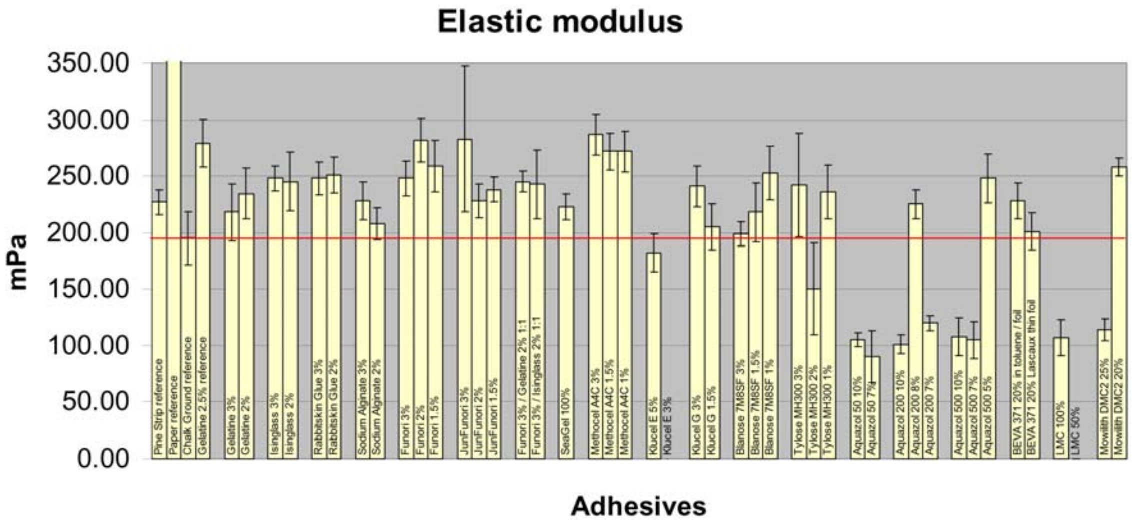
It is quite difficult to judge the synthetic adhesives, because apart from Aquazol 50 and BEVA their strength is quite dependent on the "right" concentration. In general they seem to have a lower strength, but with a certain concentration the strength can soar considerably. This happened for the Aquazol 200 8%, Aquazol 500 5%, Lascaux Medium for Consolidation 100% and Mowilith DMC2 20%.



Illus. 17 Diagram for strain. The red line indicates the strain displayed by the chalk ground reference.

The strain diagram (illus. 17) on the other hand shows quite clearly the greater tendency for plasticity of the synthetic adhesives compared to the natural ones. The worst cases are the algae glues, the SeaGel, the Funori/gelatine mix and the Klucel. Most of the other proteinaceous adhesives along with the JunFunori and Blanose and Tylose are balanced around the chalk ground in strength, often being able to flex slightly more. While the synthetic adhesives often contradict each other compared to strength, the rest tend to mirror the values for tensile strength. That means with the synthetics there can be a balance between strength and flexibility.

In terms of stiffness and reversible flexibility, the E_{mod} (illus. 18), three quarters of the adhesives



Illus. 18 Diagram for the Elastic Modulus. The red line indicates the flexibility displayed by the chalk ground reference.

are stiffer than the chalk ground reference, including gelatine. Since those are frequently used for matte paint, this higher stiffness seems to be an acceptable risk. Closest to it would be the sodium alginate 2%, the Klucel E 5%, Klucel G 1.5% and the Blanose 3%. Much less stiff are Methocel 2%, the Aquazol (apart from 200 8% and 500 5%), the Lascaux Medium for Consolidation and Mowilith 25%.

In the E_{mod} the impact of molecular structure on the stiffness becomes most pronounced. The animal and algae glues as polypeptides and polysaccharides are crystalline, meaning inflexible chains, which are cross-linked by hydrogen bonds. The cellulose ethers are modified polysaccharides, so their respective modification can make a difference, like the Methocel compared to the Klucel E. The synthetic adhesives on the other hand can be best visualised as a tangle of spaghetti with long chains able to slide past each other without breaking, flexing significantly in the process. The variations even among the same adhesive could be attributed to the molecular chains being a more amorphous than ordered structure.

It will be interesting to see, what aging does to the tensile properties. Earlier research in conservation suggests that crystalline adhesives do not change that much, while synthetics are expected to become stiffer and easier to break. [134] The chains tend to break down during aging, with the shorter rests sometimes cross-linking, but mostly just slipping free, thus loosing cohesion.

Notable among the results was the fact that higher concentration of adhesives by no means refers to higher performance. This was evident especially for Funori, Tylose, Aquazol 500 and Mowilith. The reason for this could be, that the viscosity and molecular structure affect the adhesive performance in a non-linear way.

4.3 CHOICE OF ADHESIVES FOR FURTHER TESTING

The choice of suitable adhesives was based on parameters similar to the gelatine 2.5% and chalk ground reference. Ideal adhesives would be equal or better in all four parameters.

A high strength is only desirable when accompanied with a good strain performance as well as the ability to give, before the substrate does, otherwise the adhesive might damage the paint layer.

Two adhesives will be retained for testing, since they have proven by practice, that they could still be an option, namely Funori and Lascaux Medium for Consolidation. Surprisingly their strength is not that great, but in case of the LMC this is balanced by the greatest flexibility of all adhesives.

Of suitable tensile performance seem to be gelatine*, isinglass* 2%, rabbitskin glue* 2%, sodium alginate 3%, Funori* 2%, JunFunori* 1.5%, Funori 3% / gelatine 2% 1:1*, Funori 3% / isinglass 2% 1:1*, SeaGel*, Methocel A4C* 1.5%, Blanose 7M8SF* 1.5%, Tylose MH300* 1%, Aquazol 50 10%, Aquazol 200* 8%, Aquazol 500 7%, BEVA, Lascaux Medium for Consolidation and Mowilith DMC2* 20%. All adhesives marked with a star have a higher stiffness to various degrees than the chalk ground reference.

[134] Geiger, Michel, Zumbühl

5. TESTING SEQUENCES

5.1 CRITERIA FOR ACCELERATED AGEING

UV-Ageing

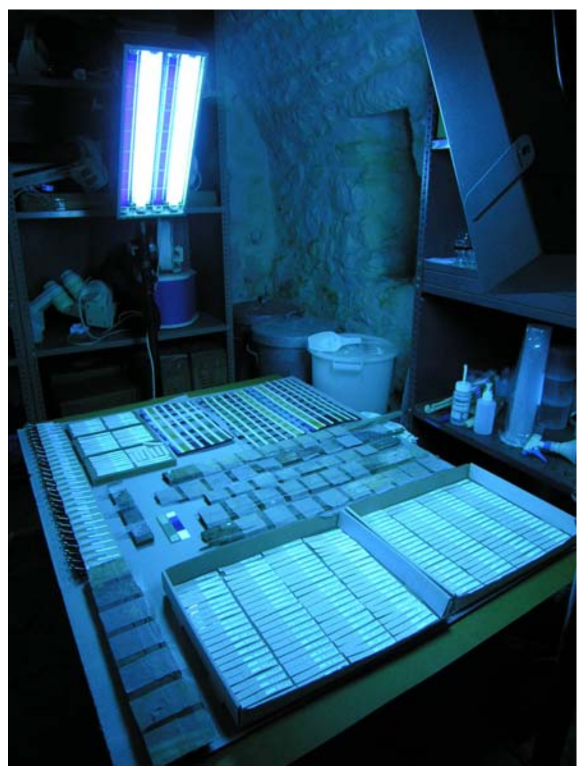
Test runs of the weathering chamber revealed that PVAc films showed no discernable change after a month.[135] This lack of response could to be ascribed to the chamber lamp's low UV output. The chamber lights showed only one peak at around 360nm, but for accelerated ageing the full range of UV-A and UV-B light is needed. Radical production or photochemical reactions depend on the presence of certain wavelengths of both these UV wavelengths; if these are not present then reactions will not occur.

Light ageing in terms of UV was carried out in a separate experiment

Separating the intense light ageing from the climate ageing may have an influence on the outcome of the testing, as combinations of both UV and climate exposure could have enforced different or more intense reactions.

A UV-ageing 'box' (illus. 19) was created with two UV lamps. Each lamp had two Black Light Blue tubes, which peak at 365nm, and two Vilber-Lourmat UV-A tubes (T-20.M), peaking at 312nm.[136] UV-C tubes were not used, because this radiation is normally filtered out by the earth's atmosphere, and does not corrrelate with naturally occurring damage.[137]

The two lamps were placed in a windowless room illuminating a raised pedestal that allowed all test samples to get the necessary



Illus. 19 The UV-ageing 'box' during the accelerated ageing in a lightless storage room

[135] Details on the Appendix CD

[136] Light source conforms to British Standard BS EN ISO 11507:2001

[137] Feller (1994), p. 91

amount of UV-light.

The exposure followed a day-and-night cycle since it is known that alternating light and dark can trigger different reactions than continuous exposure.

The overall exposure time was a total 265 hours with an average UV content of 3044 microwatt/lumen, the climate in the room monitored with a Tinytag Ultra 2 logger. Since the room was unheated, the climate was probably very close to that in unheated 17th century properties with painted ceilings, which kept the UV-ageing closer to natural environmental conditions.

Weathering Chamber

The accelerated ageing was done in a Sanyo Gallenkamp (now Weiss Gallenkamp) Fitotron Plant Growth Chamber, Model SGC097.PPX.101. The technical specifications for that chamber and climate loggings can be found on the Appendix CD.

The first step was finding a suitable cycle and program length. Most aging experiments described in conservation literature, like that of Feller, were done in ageing ovens, running at steady high temperature and humidity or with UV lights only.[138] Using ovens with high temperature nowadays is considered inadequate, because the high temperature will induce reactions that would never happen naturally in the real environments. Four useful articles about ageing in a climate chamber suggested quite different parameters and length of cycles.[139]

Since the settings and lengths varied quite a lot, it was decided the closest applicable ageing method was that of Ropret.[140] These authors researching red lead in the cathedral in Aix-en-Provence used a reflection of the yearly weather extremes found within the building. It seemed therefore appropriate to assume a similar pattern, using the worst climate data of each Scottish season within a typical 17th century building, as segment within a cycle, covering a year.[141]

A worst case scenario cycle would be Spring 8°C/60%RH, Summer 25°C/50%, Autumn 12°C/80% and Winter 3°C/99%RH. Testing these settings revealed necessary amendments due to the chamber's performance, leaving the settings as follows:

Spring 8°C/70%RH, summer 23°C/50%, autumn 12°C/80% and winter 5°C/95%RH

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138 Feller (1994), p. 63

139 Schulze et all. (2003); Aze, Vallet (2002); Güttler (2005); Ropret et all. (2007)

140 Ropret et all. (2007)

141 Climate data was collected from different properties belonging to Historic Scotland and the National Trust for Scotland, of which three were chosen as representative, see appendix.

After comparing cycle and segment lengths in the quoted literature it was decided to use three hours for each segment with lights on and off every half an hour to emulate night and day, bringing the full cycle to 12h. All test samples were subjected to 60 cycles after two days conditioning at 20°C / 55% in the chamber.[142]

5.2 CRITERIA FOR COLORIMETRY AND GLOSSIMETRY

Colorimetry[143]

Different colour changes appeared during the testing process, which were addressed with colorimetry. The first is the colour change that is induced by applying an adhesive that is not totally colourless, but has some yellowish tint such as SeaGel. The second is the are colour changes that appear during ageing. This might be because of chromophores, created within the adhesive mainly by light ageing, or because of chemical interactions between adhesive and paint layer.

The colorimetry was recorded in the CIE-L*a*b* colour space with a Konica Minolta Chroma Meter CR-40.

To measure the colour differences between the adhesives and paint layers, the Δ values, the differences between absolute values, are used (illus. 5).[144]. The complete colour deviation ΔE is the sum of the changes in three colour variables, and is not able to determine the direction of colour change, only the total amount. Its formula is

$$\Delta E^*_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

Evaluation of ΔE^*_{ab} according to DIN EN ISO 53230 (super ceded by BS EN ISO 4628-1:2004):

ΔE^*_{ab}	Evaluation
0-1	No colour difference
1-2	Minimal colour difference (“skilled eye”)
2-4	Visible colour difference
4-5	Great colour difference
>5	Extreme colour difference

[142] Conditioning conforms to British Standard BS EN 23270:1991

[143] British Standard BS EN ISO 787-25:2006 was followed as closely as possible

[144] British Standards BS 3483-A7:2006, BS 6923:1988

The test method was applied to the structural replicas and the filter paper samples dipped in the adhesive for a more independent result.

Illus. 20 With help of a template the colorimeter could be placed onto the same spots during repeated measurements

The first samples to be measured were the filter paper strips. A melinex template was placed on each strip, aligned with the dipping marker, to help measuring the same spots every time (illus. 20). This way, the instrument was able to measure seven different spots spaced in 5mm steps.

As a target value to establish the adhesives own initial colouring an average value of about 20 measurements across all plain paper strips was produced. Since the standard deviation was small, it was possible to use a plain paper strip as a reference during testing. Discolouration of the paper due to the ageing could thus be taken into account and eliminated from the results to reveal only the adhesives' discolouration.

Glossimetry

Glossimetry measures the specular gloss of a surface. By international standards specular gloss is defined as "the ratio of the luminous flux reflected from an object in the specular direction for a specified source and receptor angle to the luminous flux reflected from glass with a refractive index of 1.567 in the specular direction".[145]

For measuring gloss, polished black glass with a refractive index of 1.567 is assigned the value 100 for geometries of 20°, 60° and 85°. The different angles are suited for a more differentiated reading of all amounts of gloss. 60° is applicable for all paint surfaces, but becomes inaccurate below 10 units for low gloss and above 70 units for high gloss. Should the reading reveal values below or above this limitation, an angle of 20° with a smaller receptor aperture will give more accurate readings for high gloss and 85° for low-gloss.

[145] British Standard BS EN ISO 2813:1999

For the glossimetry an Elcometer 402 by Elcometer Instruments Ltd. was used and the test method was applied to the structural replicas and the filter paper samples dipped in the adhesive for a more independent result.

5.3 STANDARDISED STRUCTURAL REPLICAS

The structural replicas were made about eight months before the accelerated ageing took place, using old pine veneers and old thin weathered plywood. The panels were susceptible to humidity changes, so they warped readily and had already aged to some degree. This makes them quite suitable for testing how adhesive and facing tissue can cope with warping aged wood.
Though it was first thought to use these for preliminary testing, they were better paralleled in the main tests as standardised substrate to examine the adhesives independent from changing support parameters. This had the advantage to better compare chemical influences on certain pigments, pH changes and colour changes within the adhesives on a standardised substrate as well.

For the testing they were completely painted with a ground layer of whiting and 5% rabbitskin glue, applied warm, followed by stripes of pigments in rabbitskin glue.[146] Pigments Representative for of those commonly used in Scotland were chosen with the help of our architectural paint researcher[147] and ground with the glue in a mortar and applied warm. For easy application the paint was mixed to the consistency of cream which made varying pigment concentrations necessary. The pigments used were yellow ochre, ironoxide red, green made of yellow ochre and indigo, indigo, raw umber, ironoxide black and azurite.

[146] oral information Alan Simpson, Historic Scotland conservator / Joy Huning, Huning Decorations; Bath – 2007 Bristow (1996), p. 83
[147] oral information Michael Pearce, architectural paint researcher Historic Scotland - 2007

5.4 PREPARATION OF TEST MATERIALS[148]

For all sets of test samples the adhesives were prepared anew with fresh deionised water or IMS in clean jars to make sure no contamination occurred and all the samples had the same standard. After making all samples within a few days of each other, they were stored for two weeks in cool, dark conditions to dry properly in the same climate.

The first set of samples to be prepared was the one for tensile testing. Ten samples of each were prepared to make sure there were enough to get satisfactory results, since failed testing after the ageing cannot be easily repeated. The test follows the same standards and application techniques as the set for the preliminary tensile testing.

Next was the set of dipped filter papers to determine any colour and gloss changes in the adhesives more easily. A pre-test had shown that even initial colour and gloss differences between the adhesives could be detected by colorimeter and glossmeter.
Whatman filter paper 1 (circles 90mm dia) was cut into strips of 1.5cm width and dipped in the jars of adhesives up to a pencil mark and left to dry vertically on a string. The advantage of the paper was that it is of lab-grade quality, pH-neutral, absorbent, white and very matte, thus imitating the matte, absorbent paint layer. After the samples were dry they were attached by binder clips at the plain end to a balsa wood panel that had been covered with IMS cleaned melinex to prevent contamination from the wood. Cleaned melinex was placed on top and the samples were stored, covered with another panel, to prevent any light influence until the other test specimens were finished.

Two sets of pure dried adhesives were prepared for separate pH testing and solubility testing. One set was kept as a control, the other went into accelerated ageing. The samples were made by pouring 4ml of each adhesive into a small petri dish in left to dry for two weeks. After drying there was a thin layer of adhesive around the side of the dish that could be peeled off. The films were of different thickness, but this was a deliberate choice to represent the different concentrations of adhesives that would be introduced with the facing.

[148] British Standard BS EN ISO1995 was followed as closely as possible

The structural replicas that had been prepared half a year ago were faced with all adhesives, as well as the volatile ones and Eltoline tissue in 3cm strips across the coloured stripes. The volatile adhesives were both applied with and without tissue paper, to see, if it made any difference.
All adhesives were applied with the same make of brush and the tissues wetted thoroughly to ensure enough tack. After the application SeaGel displayed insufficient tack on one edge, but a reapplication was out of the question as not to upset the overall application balance. Only Eltoline was used on the replicas, because there was not enough space for more sets with different tissues, otherwise the facing area would have had to be reduced too much. Also, the replicas are intended more for the evaluation of the adhesives.

Panel No.	Paper	Adhesive
1	Eltoline	Gelatine, Isinglass, Rabbitskin glue, Funori 1.5%, Funori 2%, JunFunori, Fun/Gel, Fun/Isin, Methocel 1%, Methocel 1.5%, Blanose 1%
2	Eltoline	Blanose 1.5%, Klucel E, Klucel G, Tylose, SeaGel, Aquazole 200, 500, 50 IMS, 200 IMS, 500 IMS, LMC
3	Eltoline	Mowilith, BEVA, Cyclododecane in solvent, Cyclododecane melt, Menthol melt

Illus. 21 Original laths for the facing tests

Finally original ceiling panels for the tests were chosen, a set of laths with sufficient paint layer in indigo colouring with gilt, red lined stars (illus. 21). They had been kept in storage since they were without any display or reinstatement value because they were singular fragmented pieces. The choice seemed ideal, because the almost monochrome paint layer made comparison easier.
Strips of 6cm wide Eltoline were adhered to the surface with each adhesive as well as a second set with the Kozo tissue that had performed well in the preliminary testing.

Panel No.	Tissue	Adhesive
1	Eltoline	Gelatine, Isinglass, Rabbitskin glue, Funori 1.5%, Funori 2%, JunFunori, Fun/Gel, Fun/Isin
2	Eltoline	Methocel 1%, Methocel 1.5%, Blanose 1%, Blanose 1.5%, Klucel E, Klucel G, Tylose, SeaGel
3	Eltoline	Aquazole 200, 500, 50 IMS, 200 IMS, 500 IMS, LMC, Mowilith, BEVA
4	Eltoline	Cyclododecane in solvent, Cyclododecane melt, Menthol melt
4	Kozo	Aquazole 200, 500, 50 IMS, 200 IMS, 500 IMS, LMC, Mowilith
5	Kozo	Methocel 1%, Methocel 1.5%, Blanose 1%, Blanose 1.5%, Klucel E, Klucel G, Tylose, SeaGel
6	Kozo	Gelatine, Isinglass, Rabbitskin glue, Funori 1.5%, Funori 2%, JunFunori, Fun/Gel, Fun/Isin, BEVA

5.5 TEST RESULTS

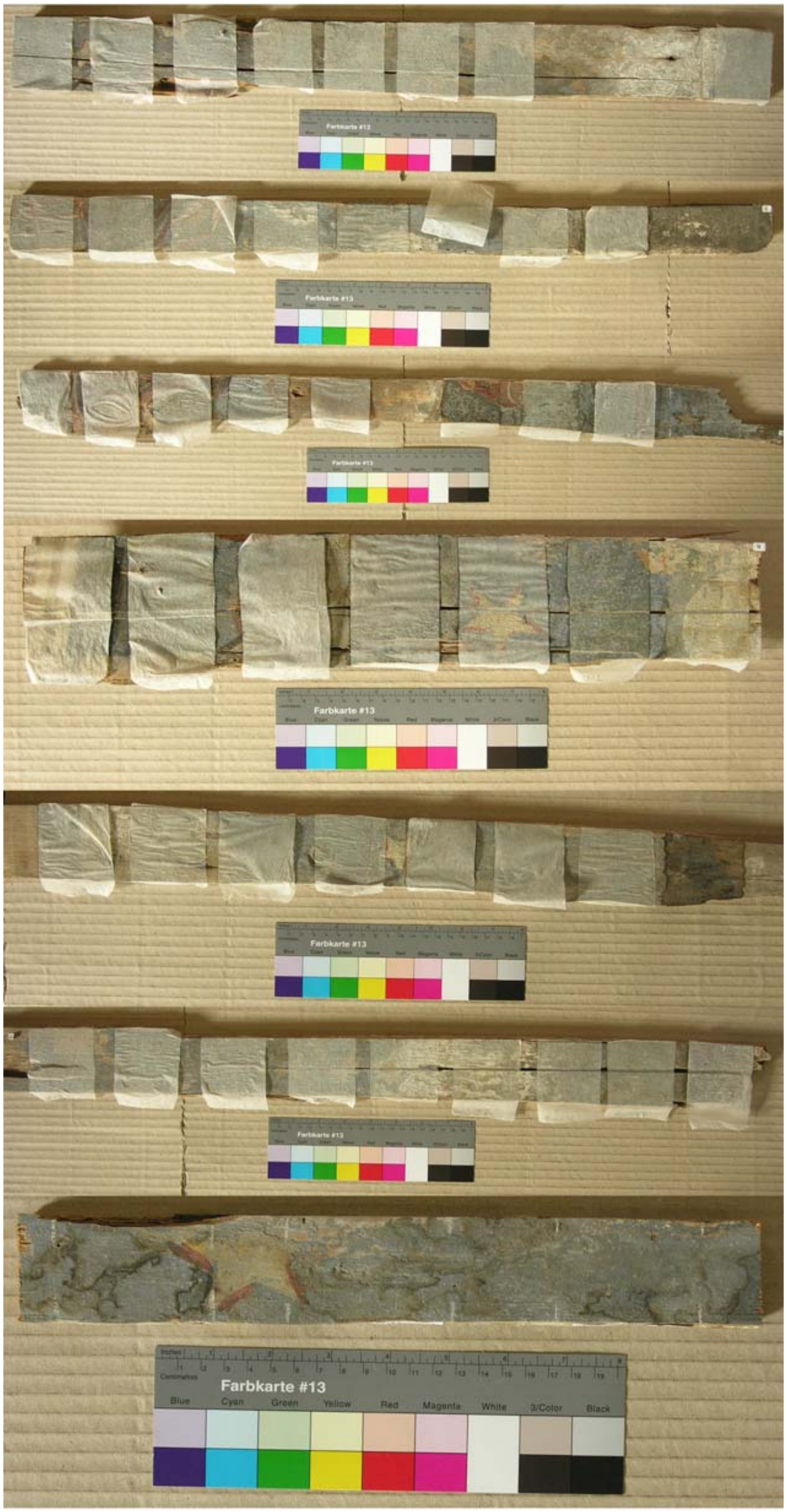
5.5.1 Optical Evaluation of Accelerated Ageing on Facings[149]

A Blue Wool Standard accompanied the complete ageing to determine the degree of ageing the test samples experienced.[150] The standard just concerns the photo stability, not the resistance against humidity-induced ageing. Swatch 1-6 discoloured, which according to Feller and indicates a good ageing stability for about 100 years in Museum conditions.[151] This number might be reduced by more irradiation and unstable climate. Since the Blue Wool Standard is a guideline, ageing in real conditions might not conform to that equation.

Some of the facings on original panels have failed partially or completely, while the number of those on the structural replicas failed less. Only the SeaGel and most of the Aquazol facings have failed partially. Partial failing can best be described as ripples in the tissue where it has come apart with lifting edges. Mowilith DMC2 is the only one that shows distinct yellowing on the facing tissue. The only facings on the original panels that still adhere flush to the paint layer are gelatine, all Funori and Funori-mix applications, Lascaux Medium, Mowilith and BEVA

[149] British Standard BS EN ISO 3668:2001 was followed as closely as possible
[150] British Standard BS 1006:1990
[151] Feller (1994),p. 7 / Gottsegen (1993), p. 131 / Thomson (1986), p.183

The following list and illustrations (22,23) describe the individual visual observations of the different types of facings after ageing; the illustrations can be viewed on the Appendix CD as well.



Illus. 22 Original panels after the completed accelerated ageing.

Illus. 23 Replica panels after the completed accelerated ageing. Notable is less rippled appearance of the facing tissues.

Optical Descriptions of Facings after Accelerated Ageing

Adhesive	Original / Eltoline	Original / Kozo	Replica / Eltoline
Gelatine	overall holding tight and fast, plastic deformation of loose tissue on right cross edge, some tiny tissue ripples, tide lines from bleeding	overall holding tight and fast, plastic deformation of loose tissue on right cross edge, some tiny tissue ripples, tide lines from bleeding	overall holding tight and fast, slight tide lines because of bleeding (ochre), yellowing, patch on indigo were the tissue is more translucent
Isinglass	overall holding fast but not as tight as gelatine, 10% of tissue one corner loose, some small plastic deformation on both cross edges, some small tissue ripples along the grain	overall holding fast but not as tight as gelatine, 25% of tissue on left cross edge loose, some small plastic deformation on right cross edge, some small tissue ripples along the grain, tide lines from bleeding	overall holding tight and fast, slight tide lines because of bleeding (ochre), yellowing
Rabbitskin	overall holding tight and fast, plastic deformation of loose tissue on both cross edges, two small tissue ripples, tide lines from bleeding	overall holding fast, 30% loose, plastic deformation of loose tissue on both cross edges, small tissue ripples, tide lines from bleeding	overall holding tight and fast, slight tide lines because of bleeding (ochre), yellowing
Funori 1.5%	overall holding tight and fast	overall holding tight and fast	overall holding tight and fast, less yellowing than plain protein glues
Funori 2%	overall holding tight and fast	overall holding tight and fast	overall holding tight and fast, less yellowing than plain protein glues
JunFunori	overall holding tight and fast	overall holding tight and fast, slight yellowing	overall holding tight and fast, less yellowing than plain protein glues
Fun/Gel	overall holding tight and fast	overall holding tight and fast	overall holding tight and fast, less yellowing than plain protein glues
Fun/Isin	overall holding tight and fast	overall holding tight and fast	overall holding tight and fast, less yellowing than plain protein glues
SeaGel	facing came apart, paint surface darkened perceptively and slightly yellowed, darkening from bleeding	facing came apart, paint surface darkened perceptively and slightly yellowed, darkening from bleeding	facing came apart on ochre, ironoxide red, black and their tide lines white, strong yellowing, tide lines because of bleeding on ochre and ironoxide red

Methocel 1%	overall holding tight and fast, two small loose tissue waves, nearly imperceptible tide lines from bleeding	facing came apart 45%, rest small tissue ripples, slight tide lines from bleeding	overall holding tight and fast, slight yellowish greying
Methocel 1.5%	overall holding tight and fast	overall holding fast and tight but extensive small tissue ripples	overall holding tight and fast, slight greying
Klucel E	holding tight and fast but extensive small tissue ripples, tide lines from bleeding	facing came apart 95%, darkening from bleeding	overall holding tight and fast, slight yellowing, some tiny tissue ripples, some loosening on right edge
Klucel G	facing came apart, slight tide lines from bleeding	facing came apart 90%, slight tide lines from bleeding	overall holding tight and fast, slight yellowing, some tiny tissue ripples, some loosening on right edge
Blanose 1%	overall holding tight and fast, 20% of facing came apart at corner, nearly imperceptible tide lines from bleeding	facing came apart 60%, rest has big tissue ripples, slight darkening from bleeding	overall holding tight and fast, slight yellowish greying
Blanose 1.5%	overall holding tight and fast	overall holding tight and fast, extensive tiny tissue ripples, plastic deformation on right cross edge	overall holding tight and fast, slight yellowish greying
Tylose	overall holding fast	overall holding fast, extensive small tissue ripples	overall holding tight and fast, slight yellowish greying
Aquazol 200	facing came apart, perceptible darkening, some fibre residue	facing came apart 80%, perceptible darkening, big tissue ripples	overall holding tight and fast, slight yellowing, loosening on half of the whites, black, green and ochre, bleeding marks on ochre
Aquazol 500	facing came apart 90%, extensive fibre residue in the middle, slight tide lines from bleeding	facing came apart 60%, rest has big tissue ripples, slight tide lines and darkening from bleeding	overall holding tight and fast, slight yellowing, loosening on half of the whites, black, green, indigo and ochre, bleeding marks on ochre
Aquazol 50 IMS	facing came apart 50%, some small tissue ripples, perceptible darkening marking out bleeding	facing came apart 90%, perceptible darkening marks out bleeding	overall holding tight and fast, some tissue ripples, slight yellowish greying, glossy bleeding marks on all colours apart from white, azure and black

Aquazol 200 IMS	facing came apart 10%, lots of tissue ripples, perceptible darkening marking out saturated area	overall holding fast but showing extensive tissue ripples, perceptive darkening marks out bleeding	overall holding tight and fast, some tissue ripples, slight yellowish greying, glossy bleeding marks on all colours apart from white, azure and black
Aquazol 500 IMS	facing came apart 95%, rest shows small tissue ripples, slight tide lines from bleeding	overall holding fast but showing extensive tissue ripples, perceptive darkening marks out bleeding	overall holding tight and fast, some tissue ripples, slight yellowish greying, glossy bleeding marks on all colours apart from white, azure and black
BEVA 371	overall tight and fast, tiny tissue ripples, white speckling typical for BEVA facings, slight darkening marking out bleeding	overall tight and fast, tiny tissue ripples, white speckling typical for BEVA facings, slight darkening marking out bleeding	overall tight and fast, white speckling typical for BEVA facings
LMC	overall tight and fast, tissue mostly translucent, perceptible darkening marking out bleeding	overall tight and fast, tissue less translucent, perceptible darkening marking out bleeding and some slight yellowing	overall tight and fast, tissue mostly translucent
Mowilith DMC2	overall tight and fast, slight yellowing perceptible, tide lines from bleeding	overall tight and fast, slight yellowing perceptible, tide lines from bleeding	overall tight and fast, tissue mostly translucent, very slight yellowing
CDD solv.	no visible difference for both faced and plain areas, some dusty accretions that also could be dirt on plain area	n/a	no visible difference for both faced and plain areas, some dusty accretions that also could be dirt on plain area
CDD melt	no visible difference for both faced and plain areas	n/a	no visible difference for both faced and plain areas
Menthol melt	no visible difference for both faced and plain areas	n/a	no visible difference for both faced and plain areas

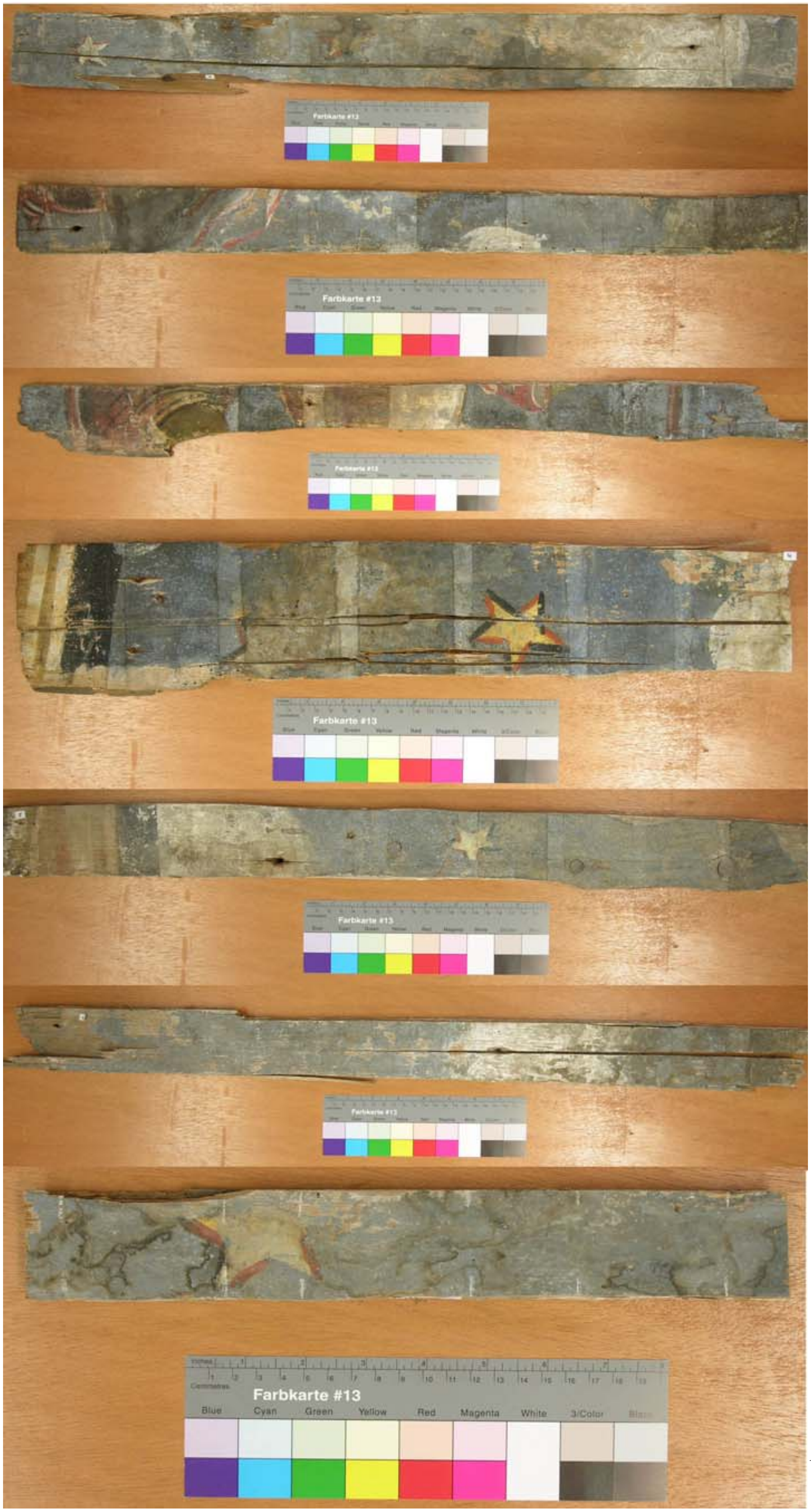
NOTE: Both tissues show comparable signs of plastic deformation (elongation cross-grain (tangential) where wood moves most) when the adhesive failed to adhere it to the surface.

Optical examination could not highlight any differences in the facings that can be attributed to the tissues, delamination with a tendency for comparable plastic deformation and rippling happens for both in an equal measure, although it is felt that both are slightly more pronounced with the Japanese kozo tissue.

The areas treated with volatile adhesives show no visible difference from the surrounding areas, there is just some powdery accretion found on the cyclododecane (solvent) area that has not been covered with tissue. Because the dissolved cyclododecane had sublimated during the UV ageing, a second application on another area of the same replica went into the climate chamber. The accretion can only be found on the second application and is easily brushed away. It can be assumed that it is attracted dust and not remains of unsublimated adhesive; the strong air circulation in the chamber would have accelerated the sublimation process.

An interesting fact is that the facings on the original panels and the replicas behaved differently during ageing. While many of the facings on the original show in parts strong delamination, all apart from the SeaGel and the Aquazol facings on replicas show no sign of delamination. This indicates that replicas for testing are not always representative, since the replicas have not experienced 500 years of natural ageing even though they are made from the same materials. The binding medium in the replicas will be stronger from the beginning and interfere with the facing adhesives, whereas the original paint layer has a binding medium that is already denaturised.

For the facing removal the appropriate solvents were used, in this case water, IMS, Stoddard Solvent and Acetone (for Lascaux Medium and Mowilith). The solvents were spread with cotton swabs, which could be used to work in the solvent in hard cases as well as for post-cleaning if necessary. Since the natural adhesives need warm water to dissolve properly, the deionised water was kept at a temperature of 55°C, so that different solubility due to different temperature could be ruled out. The optical results can be seen in the following illustrations (24,25) and performances of the adhesives during facing removal are described in the charts thereafter as well as how the treated surfaces appeared after drying. Since the facings on original panels were applied with either Eltoline or kozo tissue, they were listed separately to compare them.



Illus. 24 Original panels after the removal of the facings

Illus. 25 Replica panels after facing removal

Original / Eltoline tissue

Grading: (++) Very Good / (+) Good / (-) Medium / (o) Poor / (oo) Unsuitable

Adhesive	Removal	No Residues	No Gloss	No Sticking flakes	No Discolouration	No Darkening	Post-cleaning neccessary?	Other observations
Gelatine	(+)	(++)	(++)	(-)	(++)	(++)	no	slow penetration
Isinglass	(++)	(++)	(++)	(+)	(++)	(++)	no	
Rabbitskin	(+)	(++)	(++)	(-)	(++)	(++)	no	
Funori 1.5%	(++)	(++)	(++)	(++)	(++)	(++)	no	not that much water needed, surfaces slightly lighter
Funori 2%	(++)	(++)	(++)	(++)	(++)	(++)	no	not that much water needed, surfaces slightly lighter
JunFunori	(++)	(++)	(++)	(++)	(++)	(++)	no	not that much water needed
Fun/Gel	(+)	(++)	(++)	(+)	(++)	(++)	no	
Fun/Isin	(-)	(++)	(++)	(o)	(++)	(++)	no	slow penetration, very sticky, much water necessary
SeaGel	(++)	(++)	(++)	(++)	(-)	(+/-)	no	
Methocel 1%	(++)	(++)	(++)	(++)	(++)	(++)	no	
Methocel 1.5%	(++)	(++)	(++)	(+)	(++)	(++)	no	IMS+H2O works less well
Klucel E	(++)	(++)	(++)	(++)	(++)	(+)	no	IMS+H2O works less well
Klucel G	n/a	(++)	(++)	(++)	(++)	(++)	no	facing off already
Blanose 1%	(++)	(++)	(++)	(+)	(++)	(++)	no	IMS+H2O works less well
Blanose 1.5%	(++)	(++)	(++)	(++)	(++)	(++)	no	IMS+H2O works less well
Tylose	(++)	(++)	(++)	(++)	(++)	(++)	no	IMS+H2O works less well
Aquazol 200	(++)	(++)	(++)	(++)	(++)	(+)	no	
Aquazol 500	(++)	(+)	(++)	(++)	(++)	(+)	some	some tissue residues
Aquazol 50 IMS	(++)	(+)	(+)	(++)	(++)	(-)	some	
Aquazol 200 IMS	(++)	(+)	(++)	(++)	(++)	(-)	(some)	
Aquazol 500 IMS	(++)	(+)	(++)	(++)	(++)	(-)	no	
BEVA 371	(++)	(o)	(++)	(++)	(++)	(+)	yes	
LMC	(oo)	(o)	(-)	(+)	(++)	(o)	some	Tissue shredded by swabbing, post-cleaning unsuccessful, red paint dissolves
Mowilith DMC2	(-)	(+)	(+)	(-)	(++)	(-)	some	post-cleaning unsuccessful
CDD solv.	n/a	(++)	(++)	(++)	(++)	(++)	no	
CDD melt	n/a	(++)	(++)	(++)	(++)	(++)	no	
Menthol melt	n/a	(++)	(++)	(++)	(++)	(++)	no	

Pre-wetting helps with synthetics

The red pigment on P3 is water sensitive (can be treated with IMS and 5% H_2O)

Most water-bound adhesives have some tide lines along the tissue edge

For natural adhesives water temperature 55°C

Original / Kozo tissue

Adhesive	Removal	No Residues	No Gloss	No Sticking flakes	No Discolouration	No Darkening	Post-cleaning neccessary?	Other observations
Gelatine	(+/-)	(++)	(++)	(-)	(++)	(++)	no	slow penetration
Isinglass	(++)	(++)	(++)	(+/-)	(++)	(++)	no	
Rabbitskin	(+)	(++)	(++)	(+/-)	(++)	(++)	no	
Funori 1.5%	(++)	(++)	(++)	(++)	(++)	(++)	no	
Funori 2%	(++)	(++)	(++)	(++)	(++)	(++)	no	
JunFunori	(++)	(++)	(++)	(++)	(++)	(++)	no	
Fun/Gel	(+)	(++)	(++)	(+)	(++)	(++)	no	slower penetration
Fun/Isin	(-)	(++)	(++)	(o)	(++)	(++)	no	slow penetration, very sticky, much water necessary
SeaGel	(++)	(++)	(++)	(++)	(-)	(+/-)	no	
Methocel 1%	(++)	(++)	(++)	(++)	(++)	(++)	no	IMS+H2O works less well
Methocel 1.5%	(++)	(++)	(++)	(++)	(++)	(++)	no	IMS+H2O works less well
Klucel E	(++)	(++)	(++)	(++)	(++)	(+)	no	IMS+H2O works less well
Klucel G	(++)	(++)	(++)	(++)	(++)	(++)	no	facing off already
Blanose 1%	(++)	(++)	(++)	(++)	(++)	(++)	no	IMS+H2O works less well
Blanose 1.5%	(++)	(++)	(++)	(++)	(++)	(++)	no	IMS+H2O works less well
Tylose	(++)	(++)	(++)	(++)	(++)	(++)	no	IMS+H2O works less well
Aquazol 200	(++)	(++)	(++)	(++)	(++)	(+/-)	no	
Aquazol 500	(++)	(++)	(++)	(++)	(++)	(+/-)	no	
Aquazol 50 IMS	(++)	(+)	(+)	(++)	(++)	(-)	no	
Aquazol 200 IMS	(++)	(+)	(++)	(++)	(++)	(-)	no	
Aquazol 500 IMS	(++)	(+)	(++)	(++)	(++)	(-)	(some)	
BEVA 371	(++)	(o)	(++)	(++)	(++)	(+)	yes	
LMC	(oo)	(o)	(+/-)	(+)	(++)	(o)	some	tissue slightly torn at edges
Mowilith DMC2	(-)	(+)	(+)	(-)	(+)	(-)	some	
CDD solv.	n/a	(++)	(++)	(++)	(++)	(++)	no	
CDD melt	n/a	(++)	(++)	(++)	(++)	(++)	no	
Menthol melt	n/a	(++)	(++)	(++)	(++)	(++)	no	

Pre-wetting helps with synthetics

Structural Replicas / Eltoline

Adhesive	Removal	No Residues	No Gloss	No Sticking flakes	No Discolouration	No Darkening	No Removal Difficulties on Pigment	Post-cleaning necessary?	Other observations
Gelatine	(oo)	(-)	(++)	(oo)	(++)	(++/+)	(o) umber/azurite, (oo) green/indigo, rest (+)	n/a	facing has torn off indigo and green paint layer, tissue residues
Isinglass	(oo)	(-)	(++)	(oo)	(++)	(++/+)	(o) umber/azurite, (oo) green/indigo, rest (+)	n/a	facing has torn off azurite, indigo and green paint layer, tissue residues
Rabbitskin	(oo)	(-)	(++)	(oo)	(++)	(++/+)	(o) umber/azurite, (oo) green/indigo, rest (+)	n/a	facing has torn off indigo and green paint layer, tissue residues
Funori 1.5%	(++/+)	(++)	(++)	(++)	(++)	(++/+)	(+) umber, rest (++)	no	
Funori 2%	(++/+)	(++)	(++)	(++)	(++)	(++/+)	(+) umber/green, rest (++)	no	
JunFunori	(+)	(++)	(++)	(++)	(++)	(++/+)	(+) umber/azurite, rest (++)	no	
Fun/Gel	(+/-)	(++)	(++)	(++)	(++)	(+/-)	(+) ochre/red/chalk, (-) azurite, indigo, umber	no	slow penetration apart from ochre
Fun/Isin	(oo)	(oo)	(++)	(-)	(++)	(++/+)	(+) black/ochre/chalk, (-) red, (o) indigo, (oo) green, umber	n/a	slow penetration, facing is nearly impossible to get off some pigments
SeaGel	(++)	(++)	(+)	(++)	(o)	(-)	green much more yellowish, red/ochre dark	no	
Methocel 1%	(+)	(++)	(++)	(++)	(++)	(++/+)	more sticky on umber and slightly on pigments, slow penetration apart from ochre	no	IMS+H2O works less well

Methocel 1.5%	(+)	(++)	(++)	(++)	(++)	(++/+)	more sticky on umber and slightly on pigments, slow penetration apart from ochre	no	IMS+H2O works less well
Klucel E	(++)	(++)	(+)	(++)	(+)	(+)	indigo slightly lighter, less penetration with azurite/indigo/green	no	IMS+H2O works less well
Klucel G	(++)	(++)	(++)	(++)	(++)	(++)	less penetration with azurite/indigo/green	no	IMS+H2O works less well
Blanose 1%	(++)	(++)	(+)	(++)	(++)	(++)	indigo slightly lighter	no	IMS+H2O works less well
Blanose 1.5%	(++)	(++)	(+)	(++)	(++)	(+)	indigo slightly lighter	no	IMS+H2O works less well
Tylose	(+)	(+)	(++)	(++)	(++)	(+)	more sticky on azurite/green/umber	no	IMS+H2O works less well
Aquazol 200	(++)	(+)	(+)	(++)	(+)	(+/-)	(++)	some	water sensitivity
Aquazol 500	(+)	(+)	(+)	(++)	(+)	(+/-)	removal slightly difficult on azurite	some	water sensitivity
Aquazol 50 IMS	(++)	(+)	(+)	(++)	(+)	(+/-)	no gloss chalk/ochre/azurite/black	yes	darkening pronounced on ochre and red
Aquazol 200 IMS	(++)	(+)	(++)	(++)	(+)	(+/-)	no gloss chalk/ochre/azurite	yes	
Aquazol 500 IMS	(++)	(+)	(++)	(++)	(+)	(+/-)	no gloss chalk/ochre/azurite/red/umber	yes	
BEVA 371	(++)	(o)	(++)	(++)	(+/-)	(+)	residue on ochre	yes	
LMC	(oo)	(o)	(-)	(+)	(++)	(o)	azurite/umber/black (+), chalk (-), rest (o)	yes	tissue torn because of undissolved adhesive
Mowilith DMC2	(-)	(+)	(-)	(-)	(++)	(-)	ochre on swab	some	
CDD solv.	n/a	(++)	(+)	(++)	(++)	(++)	no	no	some dustlike accretions
CDD melt	n/a	(++)	(++)	(++)	(++)	(++)	no	no	
Menthol melt	n/a	(++)	(++)	(++)	(++)	(++)	no	no	

Pre-wetting helps with synthetics

Apart from umber and green pigments are water-sensitive

It was apparent is that all facings on original paint layer could be removed completely while on the replicas tissue residues were left from facings with protein glues, Funori/isinglass and Lascaux Medium, which were also the most difficult to remove. There the protein facings also have become slightly difficult on ironoxide red, more so on azurite and raw umber. On green and indigo and raw umber they became so insoluble that they took of most of the pigmented layer which separated from the chalk ground. By comparison isinglass displays the worst results, since it also destroyed the azurite stripe. The Funori/isinglass mixture did not destroy a stripe completely, but raw umber, green, indigo and ironoxide red were the most problematic where the tissue could mostly not be removed any more, the former two were slightly damaged as well. All of the afore mentioned and Funori/gelatine were only slowly penetrated by the water, indicating a reduced solubility as well. Interestingly, the Lascaux Medium facing that was also very difficult to remove did not damage the pigment stripes and was affected most by chalk, yellow ochre, ironoxide red and indigo, whereas on azurite, raw umber and ironoxide black it was readily soluble.

A way of measuring reduced solubility, which is undesirable, is slower penetration of the removal solvent into the tissue. In terms of slower penetration as a sign of reduced solubility only the following adhesives were mostly unaffected on the replicas; Funori, JunFunori, SeaGel, Blanose, Aquazol, BEVA, Mowilith and the volatile adhesives. The pigments that caused the most solubility decrease were azurite, green, indigo and raw umber of which both the azurite and raw umber have been identified as problematic influence on protein glues in the study by Fiedler.[152]
Looking at original paint surfaces, decreased solubility was less pronounced, resulting mostly in more flakes sticking to the facing and slightly slower penetration. In both cases Funori/isinglass was the worst offender, reflecting the results from the replicas, while gelatine, rabbitskin glue and Mowilith were a bit more soluble; isinglass was performing slightly better in comparison. The Lascaux Medium did not remove flakes, but getting both the Eltoline and Japanese tissue off without tearing them was impossible. The tissue choice seems not to have any influence in that regard, because no discernible differences in solubility between the two facing sets could be detected.

In terms of gloss changes and darkening, the natural and volatile adhesives performed best, with no change. Aquazol, especially when dissolved in IMS, did not increase gloss on the original paint surface, but visible darkening, whereas gloss on the replicas was visible on certain pigments

[152] Fiedler (2001), p. 56

and darkening was generally less pronounced. In this regard BEVA performs well, although the whitish residues take a lot of post-cleaning to remove. Worst of all adhesives in these categories are the Lascaux Medium and Mowilith, showing gloss and darkening, because they are difficult to remove completely from the surface.

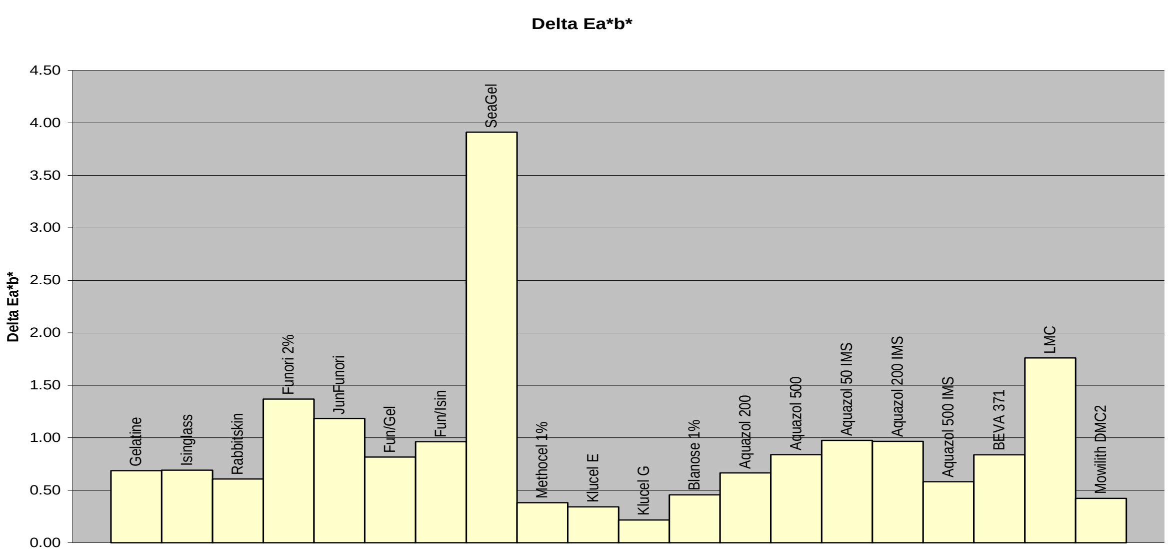
Looking at overall performance for facing removal, solubility and optical surface appearance change volatile adhesives are excellent, followed by Funori, JunFunori and the Cellulose ethers (apart from Klucel E and G), with only slightly diminished solubility on certain pigments on the replicas. The Funori mixes and most of the group of so-called synthetic adhesives, Aquazol, Lascaux Medium and Mowilith, show a poorer performance with the Lascaux Medium being worst. BEVA is the best of the group with the only objection being in necessary extensive post-cleaning.

5.5.2 Colorimetry

Paper Strips

Even by naked eye, slight discolouration of the saturated paper and tissue could be detected on the paper strips.

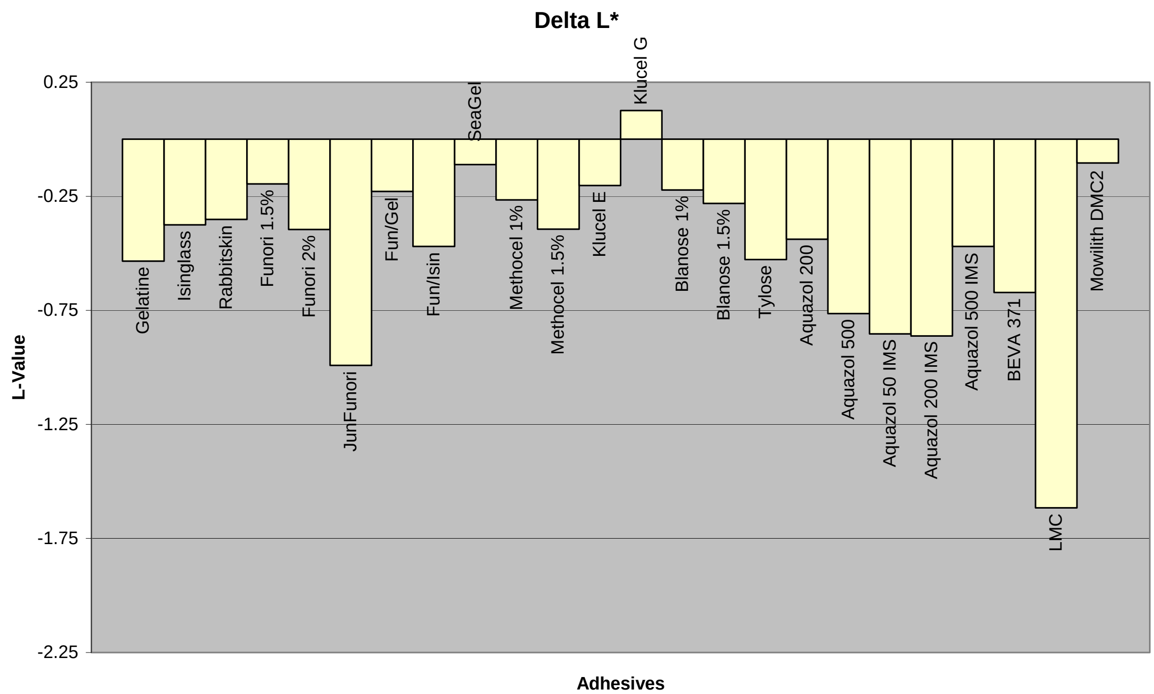
The first illustration shows the ΔE^*_{ab} value (illus. 26), comparing the colouring of the different adhesives to the "zero" value of the paper substrate.



Illus. 26 ΔE^*_{ab} diagram of initial colour differences between the adhesives

It is quite evident that there can be big differences in original colouring, the SeaGel giving the highest visible colour change. The next adhesive standing out with more than 2 is the Lascaux Medium for Consolidation. A minimal colour difference is exhibited by Funori, the Funori mixes, JunFunori, Klucel E, Aquazol 50 IMS and Aquazol 200 IMS, while the protein glues, Methocel, Klucel G, the other Aquazols, BEVA and Mowilith have no colour difference.

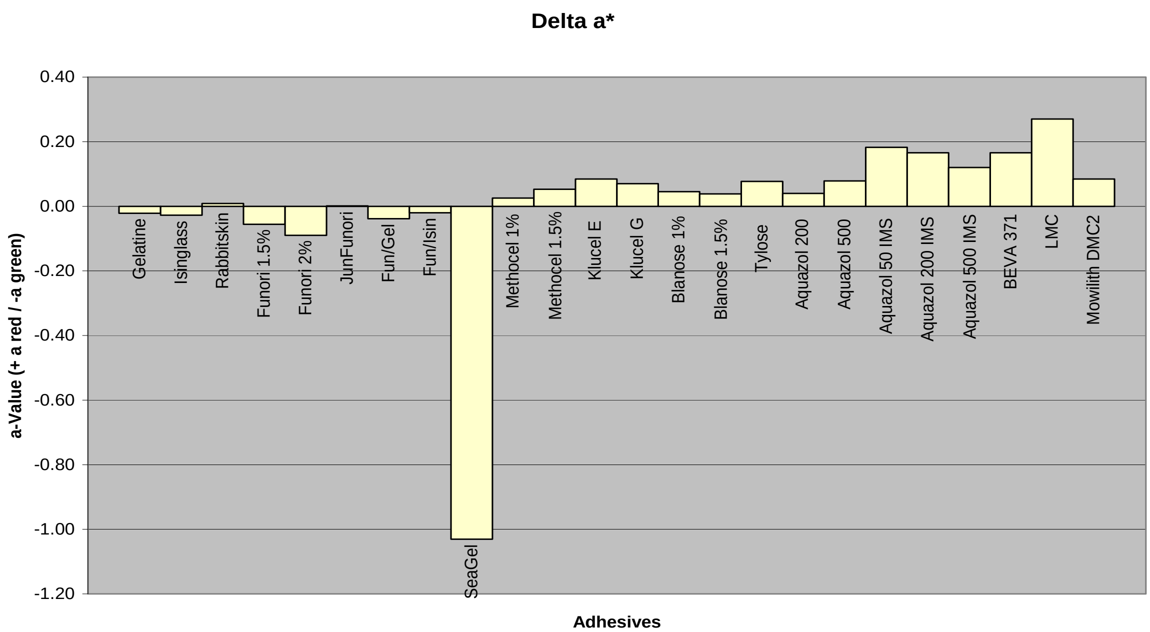
At this point the question arises, how the colour variations are distributed between the L*a*b* values, since ΔE^*_{ab} only shows the entirety of colour difference. To find out which adhesive varies most for which value, ΔL^*, Δa^* and Δb^* are charted separately in the following illustrations.



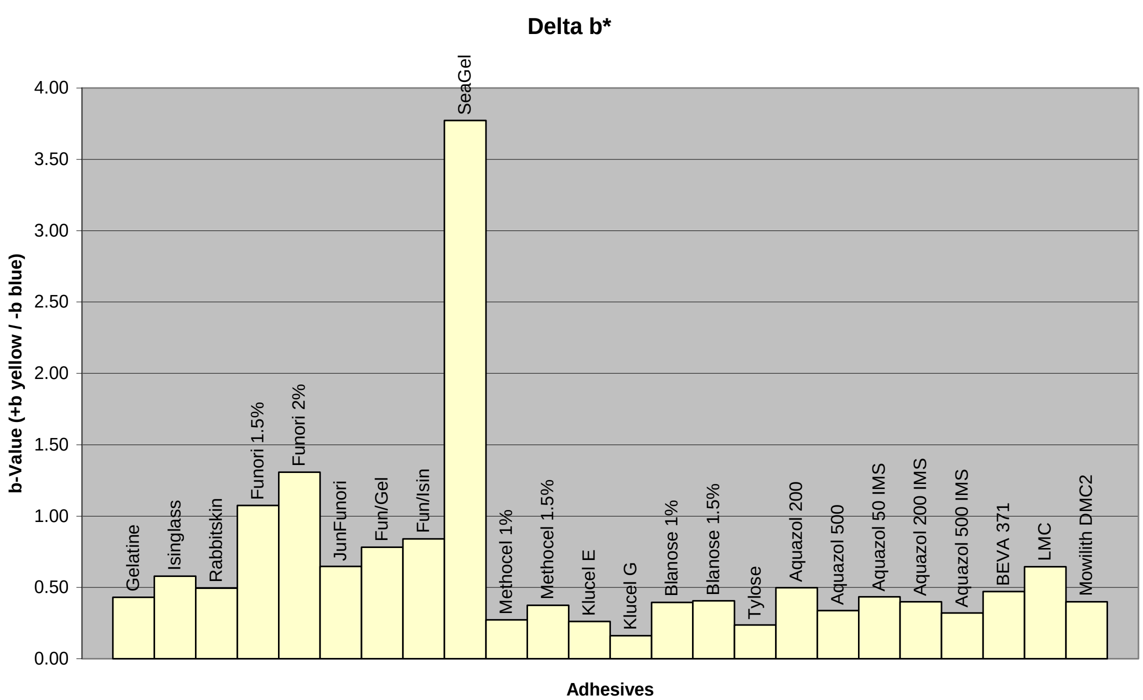
Illus. 27 ΔL diagram showing the initial brightness of the adhesives*

The brightness (illus. 27) has decreased for all adhesives apart from the SeaGel and the high ΔE values for the two Aquazols in IMS and the Lascaux Medium can now be explained through the high degree of saturation, which significantly decreased the paper's brightness. Also JunFunori showed more darkening, it can not be explained by lower viscosity due to short molecule chains or penetrating solvent, since the solution is as viscous as the less darkening Funori. The Funori-Isinglass mix, Klucel E, BEVA and Aquazol 500 IMS hold the middle ground. All other adhesives darken less than a value of about 0.5, with Mowilith without darkening. Looking at the paper strips, the darkening mostly appears as a greyish cast.

Comparing the red/green axis (illus. 28) the results are mixed. Extremely obvious with a strong green tinge is the SeaGel. Gelatine, isinglass, Funori, their mixtures and JunFunori have a much less green tendency, while Rabbitskin glue and Aquazol 200 are very slightly reddish. All other adhesives are of a more reddish tinge, with the synthetic ones the most.



Illus. 28 Δa diagram showing the initial red-green-balances of the adhesives*



Illus. 29 Δb diagram showing the initial yellow-blue-balances of the adhesives*

The colour variation for the yellow/blue axis (illus. 29) is firmly balanced in the slight yellow, whereas Funori, its mixtures and JunFunori are nearly twice as yellow as the rest. SeaGel again displays the highest amount of yellowing.

Judging from the original colour differences before ageing, SeaGel stands out as the most unsuitable, even without taking into account further yellowing through ageing and the poor tack displayed with the facing on the structural replicas.
Most of the other adhesives are “neutral” enough at the beginning.

After the two separate ageing steps the colour differences have changed quite a lot. Even by naked eye, slight discolouration of the saturated paper and tissue could be detected on the paper strips as well as on the faced dummies.
The results of the filter paper strips are as follows:

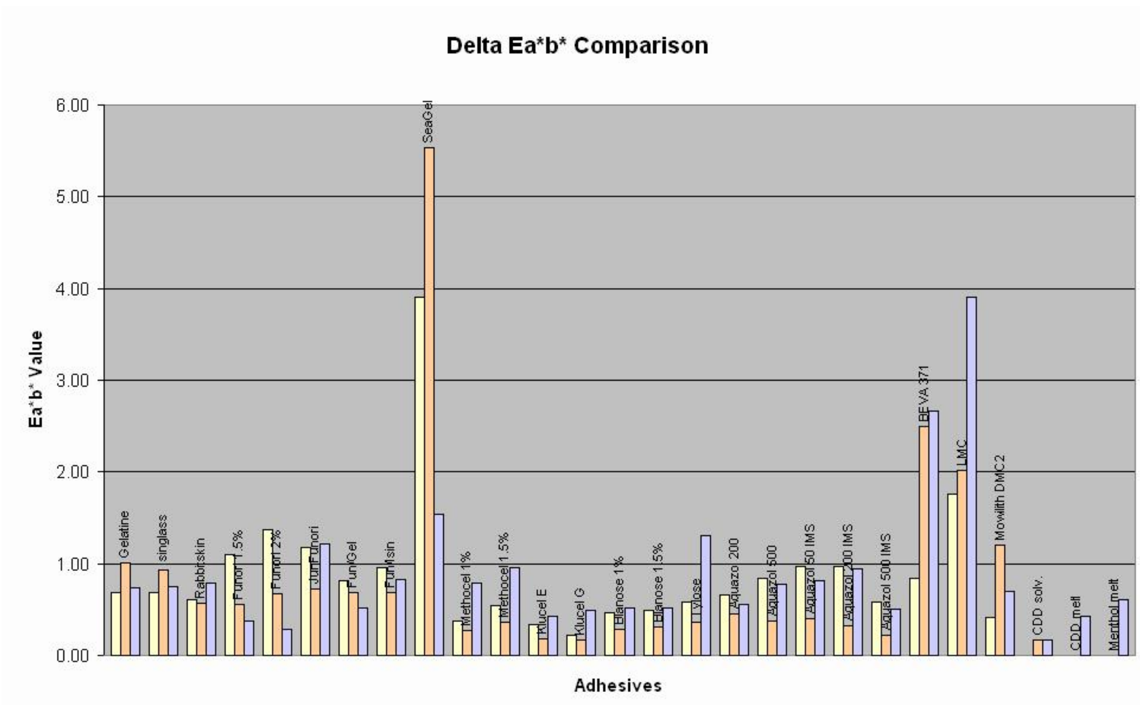
ΔE^*_{ab}	**Evaluation before ageing**	**Adhesives**
0-1	No colour difference	gelatine, isinglass, rabbitskin glue, Funori mixes, Methocel, Klucel E & G, Blanose, Tylose, all Aquazol, cyclododecane, menthol
		Funori, JunFunori, Mowilith
1-2	Minimal colour difference (“skilled eye”)	-
2-4	Visible colour difference	SeaGel
4-5	Great colour difference	-
>5	Extreme colour difference	-

ΔE^*_{ab}	**Evaluation after UV-ageing**	**Adhesives**
0-1	No colour difference	gelatine, isinglass, rabbitskin glue, Funori, JunFunori, Funori mixes, Methocel, Klucel E & G, Blanose, Tylose, all Aquazol, cyclododecane, menthol
		Mowilith, LMC
1-2	Minimal colour difference (“skilled eye”)	BEVA
2-4	Visible colour difference	-
4-5	Great colour difference	SeaGel
>5	Extreme colour difference	-

ΔE^*_{ab}	**Evaluation after completed ageing**	**Adhesives**
0-1	No colour difference	gelatine, isinglass, rabbitskin glue, Funori, Funori mixes, Methocel, Klucel E & G, Blanose, all Aquazol, Mowilith, cyclododecane, menthol

		Tylose, SeaGel
1-2	Minimal colour difference (“skilled eye”)	BEVA, LMC
2-4	Visible colour difference	-
4-5	Great colour difference	-
>5	Extreme colour difference	-

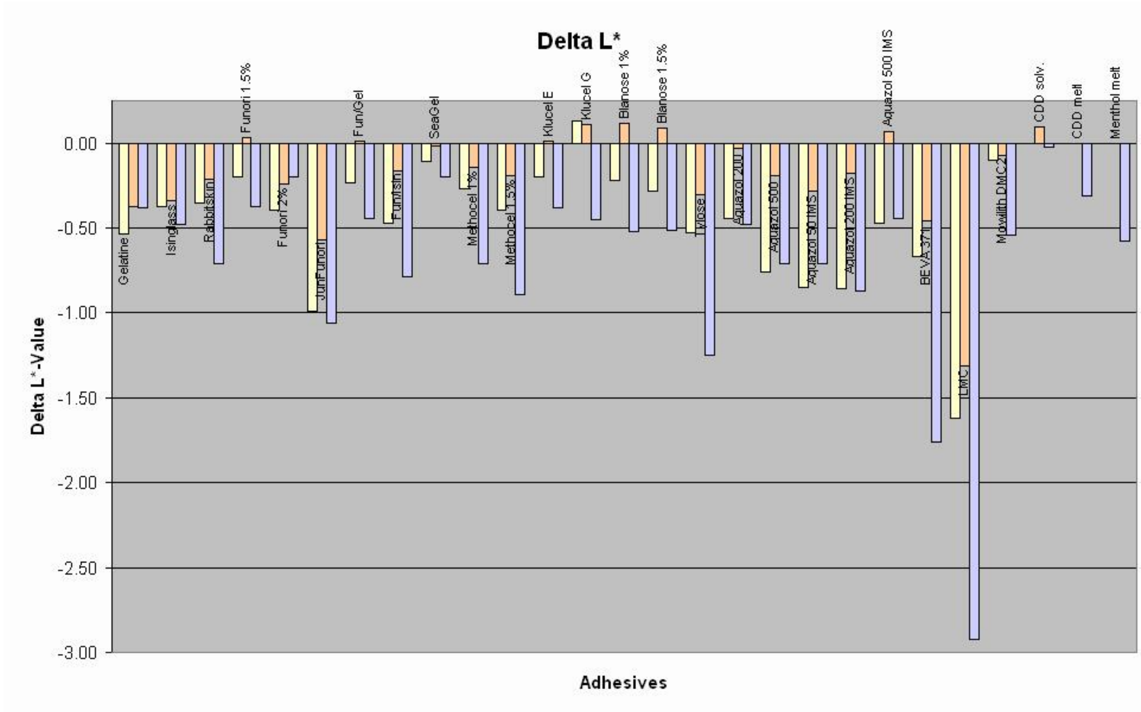
For a better comparison, ΔE^*_{ab} is charted for all adhesives for before, after UV and after complete ageing. Since the volatile adhesives are an “evaporating” covering, readings were taken only after they had completely sublimated, the before-value would be that for plain paper. The first table shows the ΔE^*_{ab} value (illus. 30), comparing the colouring of the different adhesives to the “zero” value of the paper control substrate at the time of measuring.



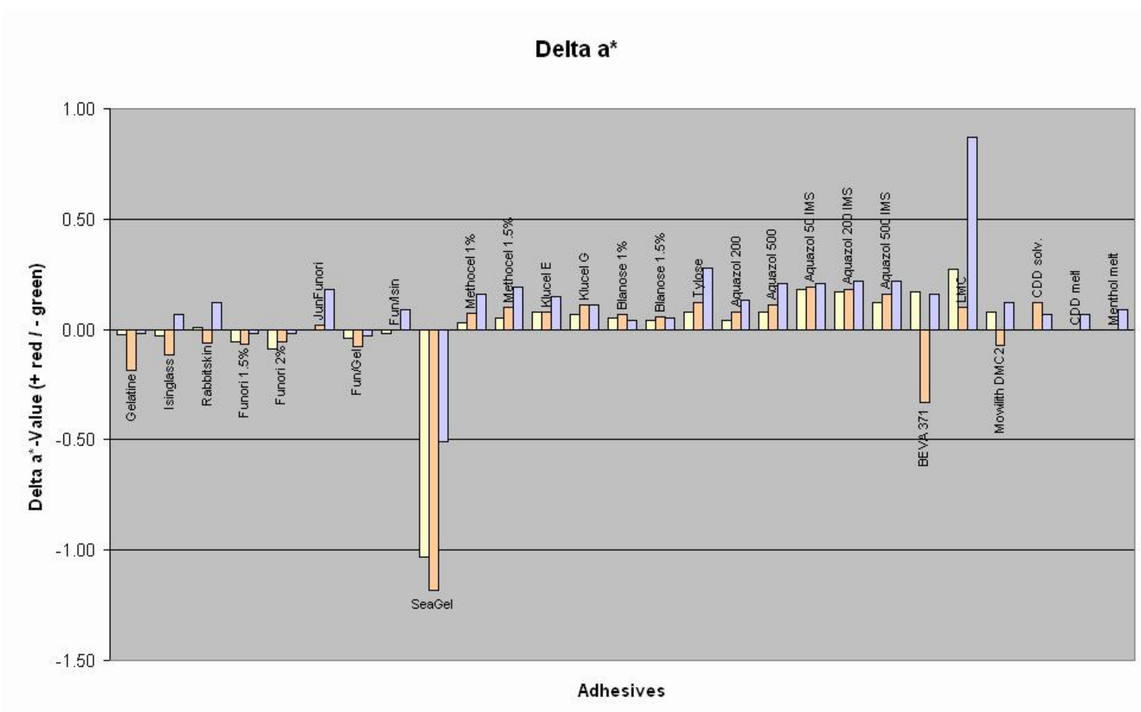
Illus. 30 ΔE^*_{ab} diagram for the paper samples before (yellow), after UV-ageing (red) and completed accelerated ageing (blue)

The brightness (illus. 31) has a major effect on the ΔE values. In all adhesives apart from the Klucel G the UV-ageing increased the brightness from the original setting and for most the climate ageing decreased it below that point. Exceptions are Funori, Aquazol 500 and all Aquazol in IMS. Even though the volatile adhesives sublimate from the surface they have had an influence on the paper by slightly darkening it permanently. The adhesives with the strongest decrease in brightness are Tylose, BEVA and Lascaux Medium.

Looking at the paper strips, the darkening mostly appears as a greyish cast.



Illus. 31 ΔL diagram for the paper samples before (yellow), after UV-ageing (red) and completed accelerated ageing (blue)*



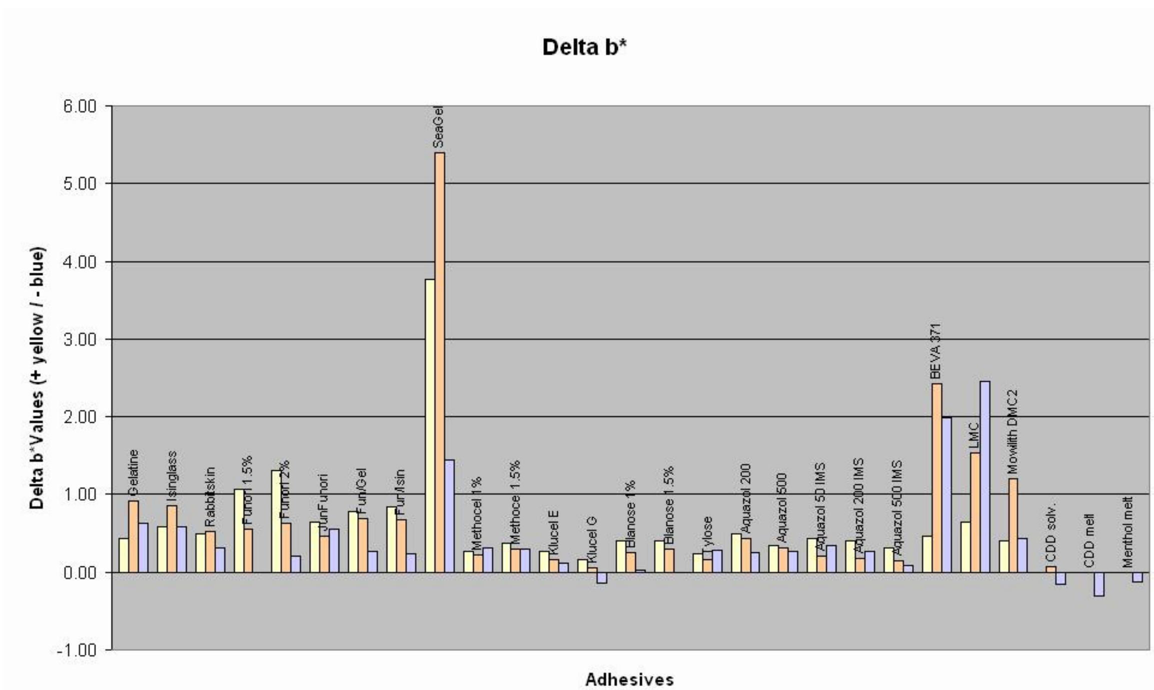
Illus. 32 Δa diagram for the paper samples before (yellow), after UV-ageing (red) and completed accelerated ageing (blue)*

Comparing the red/green axis (illus. 32) the results are mixed. Extremely obvious with a strong green tinge is the SeaGel that increased slightly after UV-ageing, but decreased to half of the original tint after climate ageing. The other natural adhesives apart from the Funori show the same tendency at a much smaller scale. A steady increase towards red is displayed by the synthetic adhesives with exception of Blanose, BEVA, Lascaux Medium and Mowilith, which behaved like the natural adhesives.

The greatest colour difference can be attributed to SeaGel, Lascaux Medium, BEVA, JunFunori and Tylose.

The colour variation for the yellow/blue axis (illus. 33) is even more diverse than for the other axis. All protein glues show increased yellowing after UV-ageing and decreasing after climate ageing. With rabbitskin glue and SeaGel the decrease fell below the original value. The yellowing in Funori and its mixes decreased steadily over the ageing process, while the JunFunori decreased more after the UV-ageing. Among the synthetic adhesives that decrease steadily are the Klucels, Blanose, Aquazol 200 and Aquazol 500 in IMS, the Lascaux Medium increases on the opposite. The Methocel shows a slight decrease first, then a slight increase again, as well as Tylose, Aquazol 50 in IMS and Aquazol 200 in IMS. BEVA and Mowilith are yellowing extensively after UV-ageing and decrease ageing after climate ageing.

For the volatile adhesives the tendency generally goes towards blue.



Illus. 33 Δb diagram for the paper samples before (yellow), after UV-ageing (red) and completed accelerated ageing (blue)*

Judging from the colour testing on filter paper alone, most chosen adhesives discolour in the non-detectable range, making them suitable. This does not apply to JunFunori, SeaGel, Tylose, BEVA, Lascaux Medium and with limitation to the Mowilith.
As is easily evident, the results are somewhat surprising, considering the partially great and conflicting colour differences. One would expect the greatest increase after the completed ageing sequence, however six adhesives (gelatine, isinglass, Funori, Funori/gelatine, SeaGel and Mowilith) display a greater photo-degradation after UV-ageing than after the completed ageing. Since the lights in chamber also went through a day/night cycle, albeit with much less UV content, the major difference would be the rapid climate change. It seems the photo-oxidative processes of these six adhesives was predominantly light activated, while in the others the processes are activated more thermally or aided by hydrolysis. The decline after the climate ageing could be attributed to the hydrolysis of the remaining free radicals. It is not clear yet, why rabbitskin glue and the Funori/isinglass mix are the exceptions to the natural adhesives.

Some adhesives showed less colour difference after ageing than before ageing, implying bleaching processes were involved in the ageing. They include Funori, the Funori mixes, SeaGel and Aquazol. In case of the SeaGel the bleaching is predominant only after climate ageing.
Looking at Funori and JunFunori, the results are different from the studies of the EMPA in Zürich, which credited JunFunori with better ageing characteristics than its natural origin.[153] Depending on the concentration of Funori the start discolouration is about equal, but where Funori shows a steady decrease in discolouration, JunFunori returns to a value slightly higher than before ageing and therefore back into the slightly visible range.

The results state the need for further research to compare sets of those adhesives being light aged and climate aged separately only to see, whether the results would consolidate these findings.

STRUCTURAL REPLICAS

To get a good average for the L*a*b* data on the structural replicas, measurements from one replica were compared against references from just this replica. Averaging all three replicas produced big deviations in some cases because each replica surface has slightly different values

[153] Swiss Federal Institute for Materials Testing and Research (EMPA) (2003)

even though they were produced from the same paint batches in the same technique. It needs to be mentioned though that the results for azurite and raw umber have to be treated with caution, because a non-stripy application had been impossible to achieve. Balancing was tried by taking the measurement on similar hues within the test squares.

Some measurements on the areas previously faced with gelatine, isinglass, rabbitskin glue and Funori/isinglass had to be declared void since the facing removal had damaged certain stripes too much.

The following list gives the ΔE^*_{ab} averages for each pigment stripe to give a general overview over how much certain adhesives changed on each pigment stripe.

ΔE^*_{ab}	**Evaluation Chalk White**	**Adhesives**
0-1	No colour difference	Menthol, CDD both, Aquazol 200 IMS, Aquazol 200, Tylose, Blanose both, Klucel both, Funori 1.5%
1-2	Minimal colour difference (“skilled eye”)	Mowilith, LMC, Aquazol 500 IMS, Aquazol 50 IMS, Aquazol 500*, Methocel both, Funori/Isinglass, Funori/Gelatine, Funori 2%, Gelatine
2-4	Visible colour difference	Isinglass, Rabbitskin, JunFunori*
4-5	Great colour difference	BEVA, SeaGel*
> 5	Extreme colour difference	-
Void		-

ΔE^*_{ab}	**Evaluation Gold Ochre**	**Adhesives**
0-1	No colour difference	CDD solv., Aquazol 500, Klucel G, Funori/Gelatine, Funori 1.5%
1-2	Minimal colour difference (“skilled eye”)	CDD melt, BEVA, Aquazol 200, Tylose, Blanose both, Klucel E, Methocel both, Funori/Isinglass, Funori 2%, Rabbitskin, Isinglass, Gelatine
2-4	Visible colour difference	Menthol, SeaGel, JunFunori
4-5	Great colour difference	Mowilith, LMC, Aquazol 500 IMS*, Aquazol 50 IMS
> 5	Extreme colour difference	Aquazol 200 IMS
Void		--

ΔE^*_{ab}	**Evaluation Ironoxide Red**	**Adhesives**
0-1	No colour difference	Cyclododecane both, Aquazol 500, Blanose 1%, Funori/Isinglass, JunFunori, Funori 2%, Isinglass

1-2	Minimal colour difference ("skilled eye")	Menthol*, Mowilith, LMC, Tylose, Blanose 1.5%, Funori/Gelatine*, Funori 1.5%, Rabbitskin
2-4	Visible colour difference	BEVA, Aquazol IMS all, Aquazol 200, Klucel both (G*), Methocel both, SeaGel, Gelatine*
4-5	Great colour difference	-
> 5	Extreme colour difference	-
Void		-

ΔE^*_{ab}	Evaluation Green	Adhesives
0-1	No colour difference	Menthol, Cyclododecane melt, Aquazol 500 IMS, Aquazol 500, Tylose, Methocel 1.5%, Funori 1.5%
1-2	Minimal colour difference ("skilled eye")	Cyclododecane solv.*, Mowilith, LMC*, Aquazol 200 IMS, Aquazol 50 IMS, Aquazol 200, Blanose 1%, Klucel G, SeaGel, Funori/Gelatine, JunFunori, Funori 2%
2-4	Visible colour difference	Blanose 1.5%, Klucel E, Methocel 1%*
4-5	Great colour difference	-
> 5	Extreme colour difference	BEVA
Void		Funori/Isinglass, Rabbitskin, Isinglass, Gelatine

ΔE^*_{ab}	Evaluation Azurite	Adhesives
0-1	No colour difference	Cyclododecane melt, JunFunori
1-2	Minimal colour difference ("skilled eye")	Menthol, Cyclododecane solv., Aquazol 200, Blanose both, Klucel G*
2-4	Visible colour difference	Mowilith, BEVA, Aquazol 50 IMS, Tylose, Klucel E, Methocel both (1%*), SeaGel, Funori/Gelatine, Funori 2%
4-5	Great colour difference	Aquazol 200 IMS, Rabbitskin, Gelatine
> 5	Extreme colour difference	LMC, Aquazol 500 IMS, Aquazol 500*, Funori 1.5%
Void		Funori/Isinglass, Isinglass

ΔE^*_{ab}	Evaluation Indigo	Adhesives
0-1	No colour difference	Klucel G, Methocel both, Funori/Gelatine

1-2	Minimal colour difference ("skilled eye")	Menthol, Cyclododecane both (melt*), BEVA, Aquazol 500 IMS, Aquazol 500, Tylose, Blanose both (1%*), SeaGel, JunFunori, Funori both
2-4	Visible colour difference	Mowilith, Aquazol 50 IMS, Aquazol 200, Klucel E, Funori/Isinglass*, Rabbitskin
4-5	Great colour difference	Aquazol 200 IMS
> 5	Extreme colour difference	LMC*
Void		Isinglass, Gelatine

ΔE^*_{ab}	**Evaluation Raw Umber**	**Adhesives**
0-1	No colour difference	Menthol, Aquazol 500, Klucel G, Funori both, Rabbitskin
1-2	Minimal colour difference ("skilled eye")	Cyclododecane both, Mowilith*, BEVA, Aquazol 500 IMS*, Aquazol 50 IMS, Aquazol 200, Methocel 1%
2-4	Visible colour difference	LMC, Aquazol 200 IMS, Tylose*, Blanose 1.5%, Klucel E, Methocel 1.5%, SeaGel, JunFunori, Isinglass, Gelatine
4-5	Great colour difference	Funori/Gelatine
> 5	Extreme colour difference	Blanose 1%, Funori/Isinglass
Void		-

ΔE^*_{ab}	**Evaluation Ironoxide Black**	**Adhesives**
0-1	No colour difference	all others
1-2	Minimal colour difference ("skilled eye")	Funori both
2-4	Visible colour difference	LMC
4-5	Great colour difference	-
> 5	Extreme colour difference	-
Void		-

* bordering onto the lower category

Something that immediately becomes evident is that in terms of colour changes the performance of the adhesives can vary quite a lot, for example for BEVA no colour difference can be observed on the ironoxide black while the difference is extreme on the green. This seems to support research about the influence of pigments on the degradation of adhesives, which was emphasised by having some azurite, indigo, and green stripes virtually destroyed by the facing removal.[154] Considering these results it seems necessary to review the adhesive performance depending on the pigment it is going to be used on, even though reactions as strong as on the replicas were not observed on the original panels. For example all adhesives apart from Lascaux Medium could be used on ironoxide black with only slight or no colour difference while on yellow ochres the range would be reduced to cyclododecane dissolved, Aquazol 500, Klucel G, Fun/Gel, Funori 1.5% for no difference and cyclododecane melt, BEVA, Aquazol 200, Tylose, Blanose, Klucel E, Methocel, Fun/Isin, Funori 2%, rabbitskin, isinglass and gelatine.

For the detailed Δ-values, whose extensive charts can be found on the Appendix CD, generally the results tend to deviate in both directions apart from a few which lean almost totally towards one direction. This is true for the brightness of gold ochre, which is darkened to various degrees by all adhesives except melted cyclododecane. Both indigo and ironoxide black tend mostly towards an increased greenish tint, apart from cyclododecane on black and SeaGel on indigo.

Among the adhesives which have the least colour changes would be Funori, Klucel G, Blanose 1%, Aquazol 500 and the volatile adhesives whilst more differences are encountered with Funori/Gelatine, Methocel, Blanose 1.5%, Tylose, Aquazol 200, Aquazol 500 IMS and Mowilith. The most amount of differences for all stripes is found for rabbitskin glue, Funori/Isinglass (2 void), SeaGel, Aquazol 50 IMS, Aquazol 200 IMS, Lascaux Medium and BEVA. Considering the void measurements for gelatine and isinglass, they would be placed in the middle field.
It has become quite obvious that dissolving Aquazol in IMS will produce more discolouration than dissolving it in water. This might be due to the higher gloss that was produced, because this is definitely true for the Lascaux Medium, the data indicates a massive increase in brightness although optical examination revealed a darker, saturated colour.

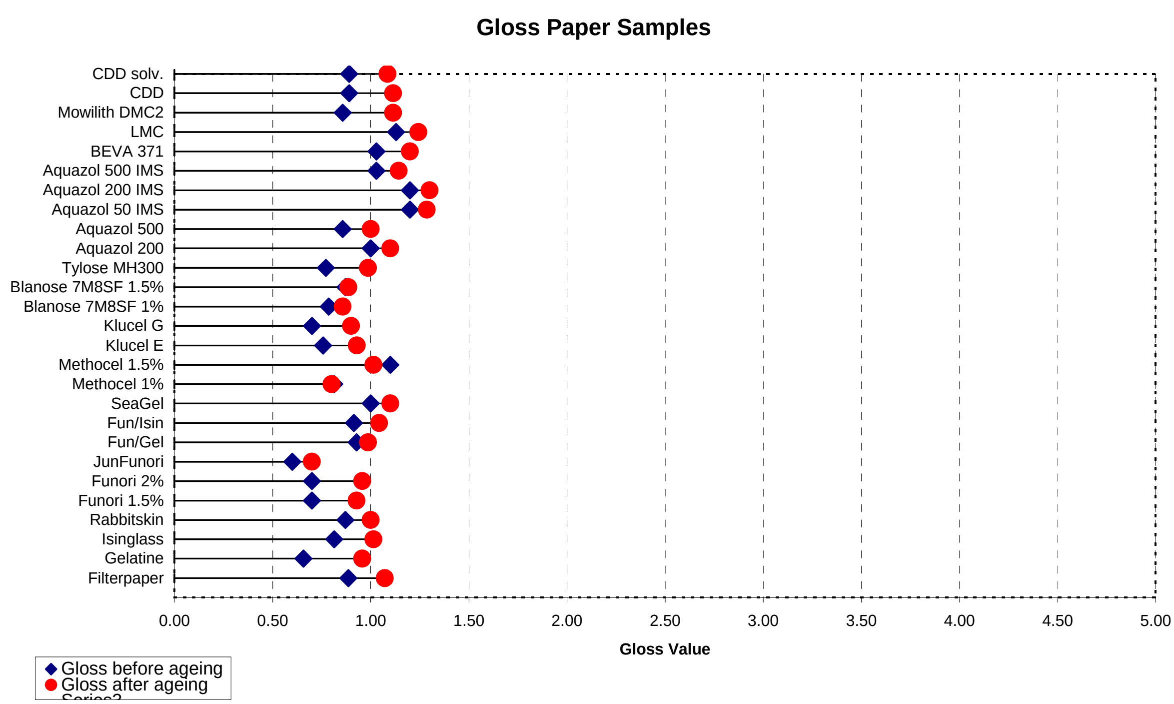
5.5.3 Glossimetry

The gloss was measured at an angle of 85° for more accuracy on the matte surface. Comparing the gloss of the adhesives, there is hardly any difference to the filter paper's matte appearance, bearing in mind the strips were just dipped in for few seconds. The amount of adhesive will be probably less than if brushed on, but this application leaves a more evenly distributed layer to get

[154] Schilling, Khanjian (1996), p. 126 / Fiedler (2001), pp.52-60

better measurements. It remains to be seen, if there is detectable gloss after the removal of the facings.

The specular gloss (illus. 34) on the filter paper has not changed very much from before the ageing, even though the average has risen very slightly. The amount is not big enough to specify it as significant. Taking this into account, most adhesives have stayed about the same or have become a bit more matte with a tendency towards the value of the filter paper. Vincent Daniels[155] explained this as a rise in the refractive index of the adhesives as the residual solvent evaporates more and more. This reduces the scatter and as additional effect the refractive indices of the paper and the adhesives will get closer.



Illus. 34 Comparison of gloss on paper samples before and after accelerated ageing

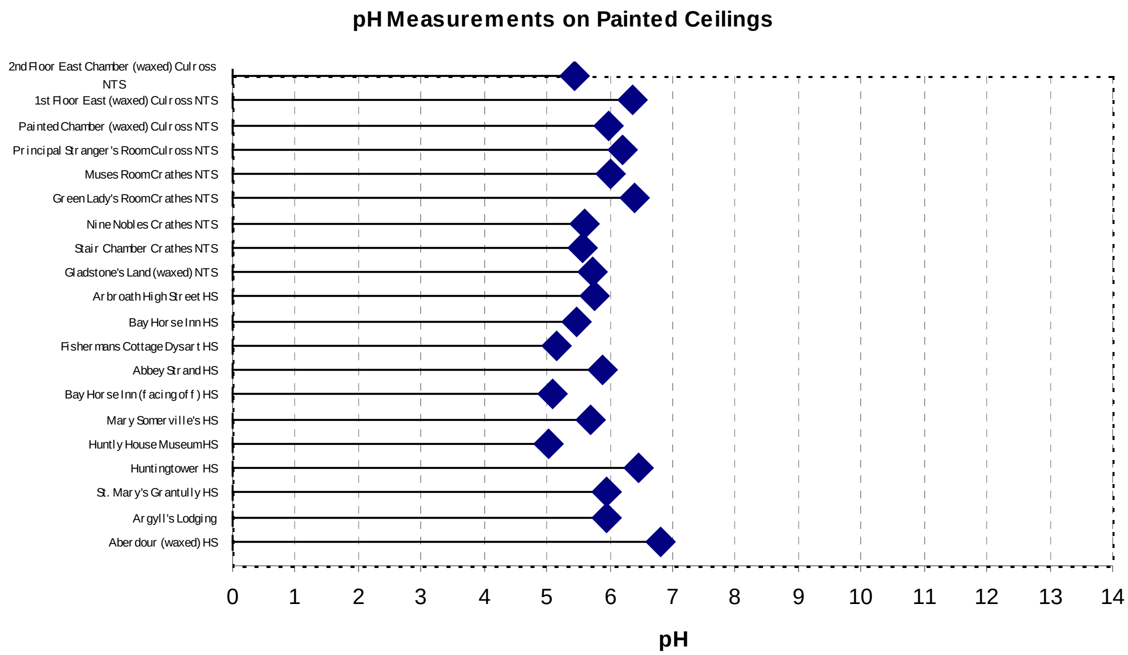
Glossimetry was also attempted on the replicas, but incompatibility of the instrument with the uneven surfaces after ageing and the size of the aperture versus the test area prevented conclusive results to the point where optically matte surfaces were classed as glossy and vice versa. Therefore the gloss on the replicas was determined by optical inspection of the surfaces after facing removal with the results detailed in sub-chapter 6.4.1.

[155] Dr. Vincent Daniels, Research Fellow V&A Conservation Department, Email 22/04/2008

However, the results from the paper strips can still be considered as valid, since the instrument sat securely on the test surface and the base for the strip during measurement was the same filter paper, unaged beforehand and aged afterwards, to minimize influences because of the instruments bigger aperture.

5.5.4 PH-Tests

To establish what kind of pH-climate can be found on the painted ceilings, several belonging to Historic Scotland and the National Trust, were tested. This formed a guideline for which pH would be beneficial to the paint layer and which adhesives might change the surface pH too much.



Illus. 35 pH measurements taken from the paint surfaces of different painted ceilings in the National Trust for Scotland and Historic Scotland estate

As can be seen from the above chart (illus. 35) the average pH is 5 – 6. Aberdour is the only neutral one found. For the low pH on panels from the Bay Horse Inn and Arbroath High Street (both in storage) there is no explanation yet, since there is no significant difference in materials and condition between the two and other panels in storage. Others might even have less thick paint layer and exposed wood. Raised pH levels could have been induced by wood acids. An interesting observation was made during the consolidation of the Stobhall ceiling in Perthshire.

The untreated ceiling had a pH of about 6 that was measured with wetted pH strips. After treatment with gelatine the surface became slightly more acidic for several hours, but the pH reverted to around 6 again when measured after four days. There seemed to be a buffering effect present on the paint surface.

The pH difference between the two waxed ceilings, Aberdour and Gladstone's Land, can be explained by the thickness of the remaining wax. The layer at Aberdour had not been reduced, while the other had, thus revealing access to the hydrophilic paint layer.

To compare the pH values for the different adhesives, the pH was measured in the liquid adhesive, on pure dried adhesive (before and after ageing) and on the untreated aged original test panels.

The average pH on the original test panels is 6.4 with the red on one of the panels being 0.3 lower. The measurements are slightly less acidic than most other tested ceiling surfaces, but still conform to the guideline measurements.

On the replicas random sampling across the treated areas gives an average of pH of 6.9 with no significant difference between the paint stripes. The lower acidity can maybe be attributed to the use of less acidic rabbitskin glue as binding medium of the paint layer.

The following chart gives an idea about the different pH values of the pure adhesives.

Adhesives	**pH fresh**	**pH control**	**pH aged**	**pH original panel aged**
Gelatine 2.5% reference	5.70	5.61	5.65	6.55
Isinglass 2%	6.90	5.74	6.78	6.43
Rabbitskin Glue 2%	6.07	5.60	5.29	6.23
Funori 2%	6.73	6.92	8.00	6.58
Funori 1.5%	6.90	6.90	8.35	6.45
JunFunori 1.5%	7.11	7.12	7.97	6.58
Funori 2% / Gelatine 2% 1:1	6.85	6.19	6.44	6.50
Funori 2% / Isinglass 2% 1:1	7.00	6.12	7.18	6.41
SeaGel 100%	7.14	6.38	6.42	6.59
Methocel A4C 1.5%	6,94	6.28	7.27	6.43
Methocel A4C 1%	6.03	6.90	7.77	6.52
Klucel E 5%	6.75	6.70	7.43	6.56
Klucel G 1.5%	7,24	7.19	8.16	6.57
Blanose 7M8SF 1.5%	7,32	7.18	7.61	6.42
Blanose 7M8SF 1%	7.40	7.20	7.49	6.65
Tylose MH300 1%	6.94	7.49	7.64	6.55
Aquazol 200 8%	6.22	7.13	7.37	6.53
Aquazol 500 5%	6.33	7.37	7.82	6.36 / 6.14 red
Aquazol 50 10% IMS	5.59	7.31	7.35	6.41

Aquazol 200 10% IMS	5.65	7.09	7.17	6.28
Aquazol 500 7% IMS	5.81	7.19	7.14	6.41
BEVA 371 30% Stoddard Solvent	4.94	5.83	5.80	6.72
LMC 100%	8.02	5.43	5.68	6.68
Mowilith DMC2 20%	4.20	5.93	5.45	6.44
CDD solv.	n/a	7.28	n/a	6.61
CDD melt	n/a	7.25	n/a	6.71
Menthol melt	n/a	7.27	n/a	6.44

Most adhesives have a wet pH of 6-7 apart from the BEVA and Mowilith, which are quiet acidic and LMC, which tends towards alkalinity. The wet and aged surfaces of the volatile adhesives could not be tested because of the waxiness when fresh that might clog the probe and their non-existence after ageing.

On drying most pH values tend towards 6-7, being near neutral. Exceptions are the protein glues, BEVA, LMC and Mowilith, which have become only slightly acidic with values between 5 and 6. This change has been observed for BEVA and Mowilith DMC2 in the studies by Down.[156]

The accelerated ageing has not changed the pH for most adhesives enough to be concerned. Noticeable however is isinglass, which gained one pH level to become neutral and the Funori and JunFunori, which now show a tendency towards alkalinity with about 8. If the pH levels of the pure dried adhesive are compared to the original surfaces after removal of the facings (testing the facings before ageing might have changed other test results), it seems as if the buffer effect that had been observed at Stobhall has come to play here as well as the chart above shows. All pH are in the range of the values from before the application of facings.

The pH testing has shown that although the liquid adhesives might have an acidic or alkaline pH or change to one through ageing in their pure form, on the original paint layer the pH settled down to the value it had been before the treatment regardless of initial differences in the adhesives.

Even on the replicas there was no case of pigment affliction that could be attributed to pH change, especially with the Funoris, BEVA, Lascaux Medium for Consolidation or Mowilith that showed notable changes in pure form.

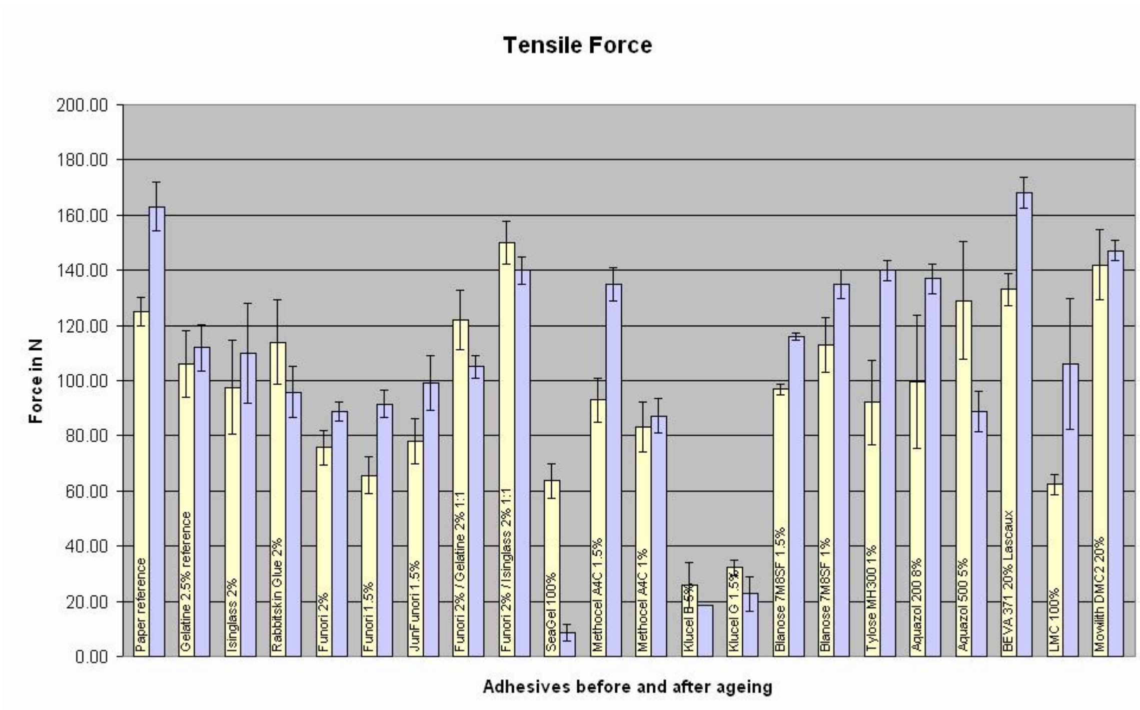
Thus it can be assumed that none of the tested adhesives should pose a threat to the common pigments found on Scottish painted wooden interiors.

[156] Down (1996), pp. 24-25

5.5.5 Tensile Testing Post-Ageing

For the tensile comparison between unaged and aged adhesives, the aged samples were tested and the results compared to the corresponding preliminary test results. The aged samples were kept at room temperature for a week in the studio before they were tested.

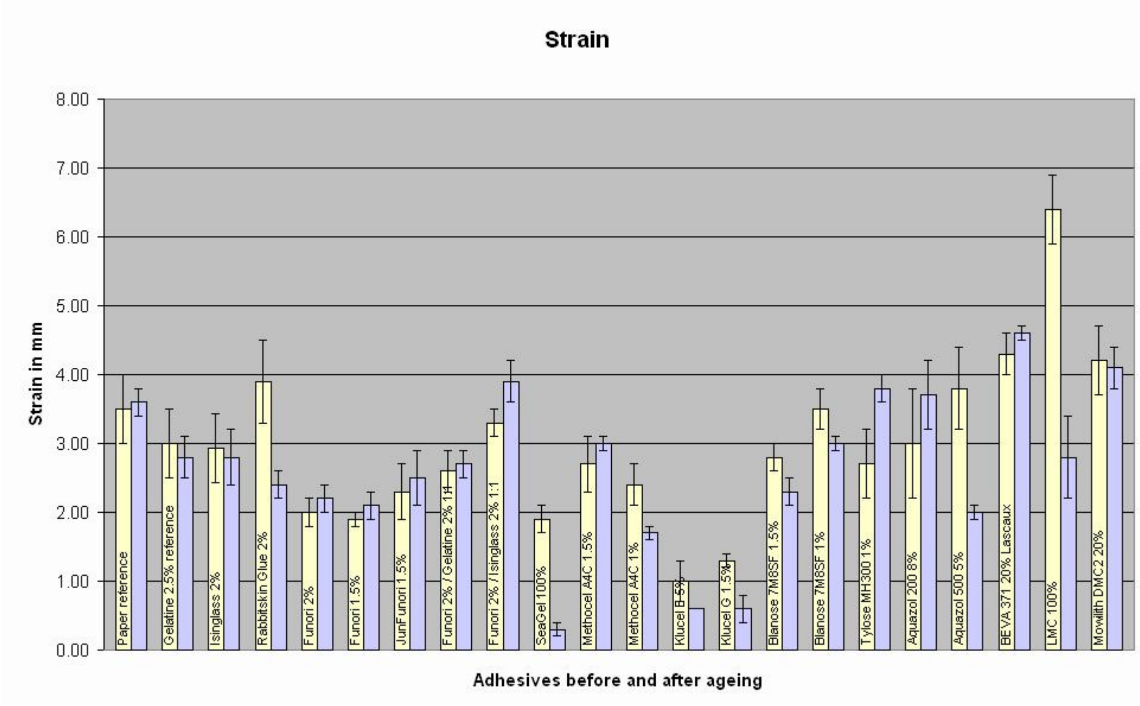
In the following diagrams the results for tensile strength, strain and elastic modulus are compared between before and after ageing.



Illus. 36 Tensile force (Fmax) diagram comparing before and after accelerated ageing

As can be seen in the tensile force diagram (illus. 36), there is a predominant increase in tensile strength after aging although considering the analytical error, gelatine, isinglass, rabbitskin glue, Methocel 1%, Klucel G and Mowilith have stayed unchanged. The increase in the Funori mixes seems mainly due to the Funori part in it which showed a definite increase. BEVA shows the highest strength with more than 160N, though the highest increase rates were achieved by Methocel 1.5%, Tylose, Aquazol 200 and Lascaux Medium and the strongest decrease by Aquazol 500. Klucel E, Klucel G, and SeaGel in particular have further decreased from their already low tensile strength.

Most synthetic adhesives show a tensile strength which is between 30N and 50N higher than the proteins and polysaccharides with exception of Funori / isinglass.



Illus. 37 Strain (Strain at max) diagram comparing before and after accelerated ageing

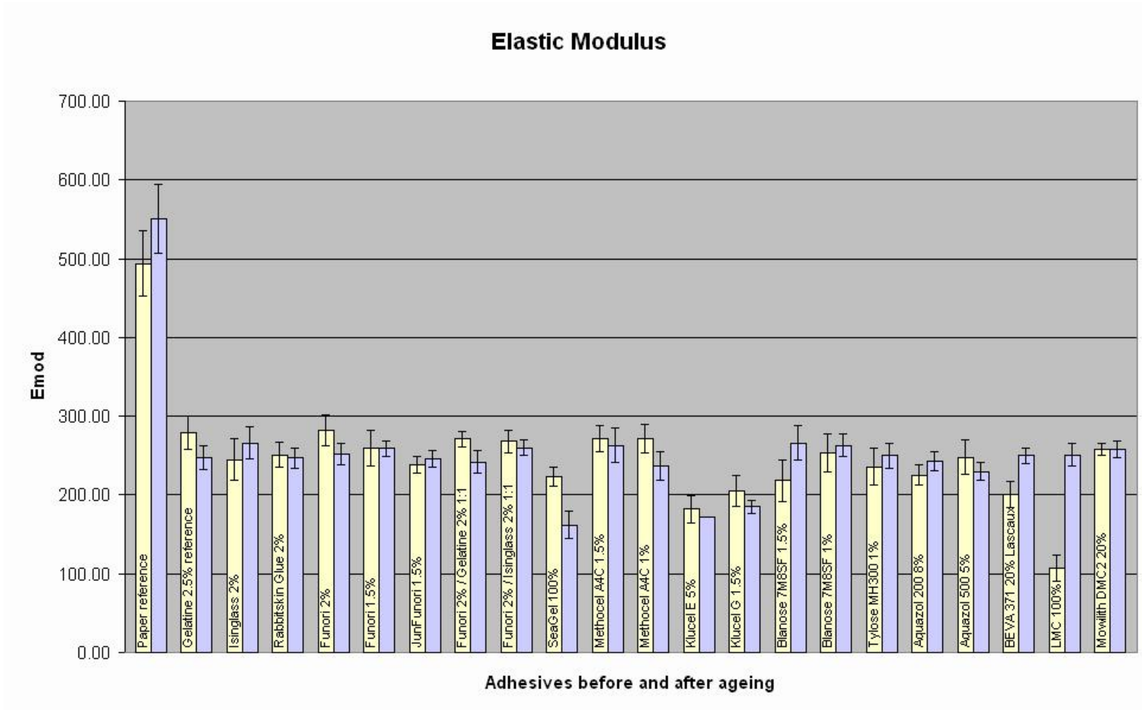
There are less differences in the strain comparison (illus. 37) which reflects the plasticity of the adhesives. Two thirds of the adhesives have tendencies to lose plasticity, especially rabbitskin glue, SeaGel and Lascaux Medium. Tylose and the Funori / isinglass mix are the only ones to show visible increase.

Considering the analytical error again changes in the strength of gelatine, isinglass, Funori, JunFunori, Funori / gelatine, Methocel 1.5%, Aquazol 200, BEVA and Mowilith were insignificant.

There is a slight tendency for the synthetic adhesives to retain more plasticity than the protein and polysaccharide glues.

The picture that is being presented by the elastic modulus (illus. 38) is quite interesting because only four adhesives have shown a notable difference after ageing with the rest accountably unchanged and tending to approximately 250 mPa. SeaGel is the only one with increased flexibility while Blanose 1.5%, BEVA and Lascaux Medium became more brittle. An increase in brittleness often denotes deterioration processes like cross-linking and chain-scission which seem not to be the case here, considering the analytical error margins which are much smaller than those for force and strain and therefore should not blur the results too much.

Most flexibility is still inherent to both Klucels and SeaGel, but Lascaux Medium has become twice as brittle as before.



Illus. 38 Elastic Modulus diagram comparing before and after accelerated ageing

Comparing all three diagrams it seems that the flexibility-brittleness ratio is mostly unchanged by the accelerated ageing which is surprising because the non-crystalline adhesives were generally expected to show greater differences in the elastic modulus.

Since SeaGel is basically a protein glue, which are considered brittle, it is thought that the increased flexibility could be caused in conjunction with the additives. They take up 3.5% to the 13% solid contents in the liquid.

The increase in brittleness for Blanose 1.5%, BEVA and Lascaux Medium could be ascribed to some cross-linking in the polymer structure. Since the Lascaux Medium has been thoroughly tested by Lascaux during its development, reporting no chemical changes during accelerated ageing, this is rather surprising.[157]

Changes because of the ageing are more obvious in this test series in the changes in plasticity and tensile strength.

The loss in plasticity which can be observed for most adhesives can be attributed to the ageing processes of cross-linking and chain-scission, activated by UV light, oxidisation and hydrolysis,

[157] Hedlund, Johansson (2005), p. 437

which restrict the movement of the polymer chains within the adhesive and reduce the amount of strain it can take. The strong reduction in plasticity for rabbitskin glue, SeaGel, Klucel, Aquazol 500 and Lascaux Medium is probably caused by a high rate of chain-scission. Surprising is the variety of results between different concentrations of the same adhesive. As can be seen with the Aquazol even chain length can result in opposite effects concerning the strain.

The increase in strain in some of the adhesives could be attributed to a break in bonds between chains which now are able to slide alongside each other more than before, resulting in more plastic deformation before the 'backbone' of the adhesive gives.

The amount of tensile strength recorded for the different adhesives reflects the ageing processes even more. Those adhesives with an increased strength after ageing would likely have experienced a greater amount of cross-linking, making the bigger number of bonds difficult to break, while those with decreased strength may have experienced more chain-scission making adhesion failures easier.

The findings by Geiger and Michel[158] are supported by this testing, but considering the analytical error the better performance of JunFunori over Funori is not distinctive but both were more plastic than before the ageing which can be beneficial for a facing adhesive.

Accelerated ageing seems to have had the least influence on the tensile properties of the protein glues. SeaGel has to be regarded differently because of the multitude of additives the other tested protein glues do not have.

The synthetics seem to have been affected the most by the accelerated ageing, in most cases the adhesive quality possibly being more affected by cross-linking than by chain-scission. To understand how these changes influence their performance as facing adhesive the tensile testing results are compared to the facing observations in the next chapter.

Among the adhesives which could be problematic when considering tensile testing alone are SeaGel, Klucel E, Klucel G and Lascaux Medium. In the case of the BEVA it might well be possible that the high tensile strength cannot be balanced by the slight increase in plasticity, causing undue stress for paint layer and facing.

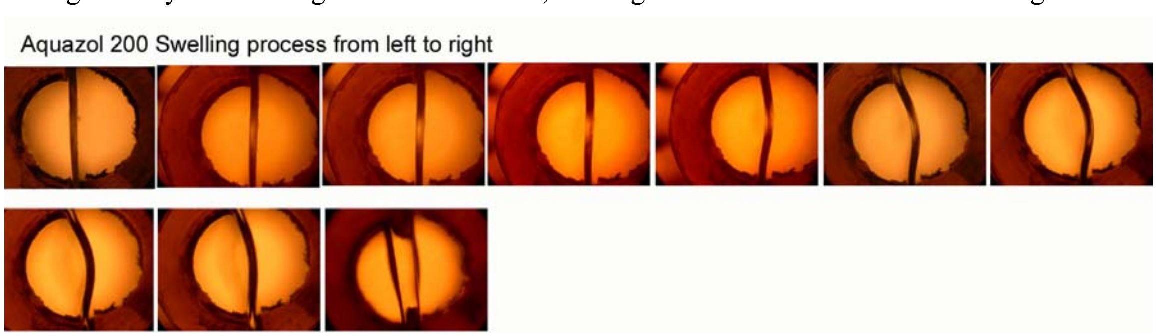
[158] Geiger, Michel (2005), p. 198

5.5.6 Solubility Testing

Illus. 39 Adapted container for swelling tests. The safety pin presses the two halves of a cut polypropylene tube together, which in turn hold the adhesive film in cross-section under the microscope.

It was thought to use the swelling test after McCrone to determine the solubility of the adhesives before and after ageing. Different methods were tested to see which would yield the best results and the one used at Berne University of the Arts was chosen (illus. 39).[159] In this method thin dried adhesive films are clamped into a specifically designed contraption and placed into a small clear container with saturated solvent atmosphere. The samples can be observed and photographed under a microscope for a given time frame. Thereafter the swelling is calculated from the length and width of the cross-section with the computer program ImageJ.
Filling a small petri dish with 4ml of adhesive each and leaving them to dry created the films for the testing. After drying the adhesive film coating the sides of the dish can be removed and cut to 1mm x 1mm squares. Pouring the adhesives on melinex for films did not work because film formation for some adhesives was incoherent due to high surface tension.

According to preliminary testing this method was producing successful results with preliminary test samples (illus. 40). Unfortunately this was not the case with the sets prepared for the real testing. Mostly no swelling could be detected, although there had been distinct swelling from the



Illus. 40 Swelling process of Aquazol 200 in a water saturated atmosphere as seen through a microscope at x5 magnification every two minutes

[159] A detailed description can be found in the diploma thesis of Francesca Attanasio, available online as pdf at www.hkb.bfh.ch/diplomarbeiten05.html

same adhesives (different batch) before, rendering this test method useless.

Due to the tight time frame it was decided to reuse the already prepared and aged (one set) samples for weighing. An amount of test material was put into an Eppendorf container and 1ml of the respective solvent added. For the adhesives that need to be dissolved warm (proteins and polysaccharides), the water was heated to 55°C like for the facing removal.
The test material was left in immersion for 5 minutes before the excess solvent was removed with a very fine syringe to leave just the undissolved residues. Since all adhesives had experienced various states of swelling the weight directly after immersion was more than the dry weight. Therefore, all samples were given away for being freeze-dried over night to remove all solvents.[160] On return the samples were weighted again and the difference recorded. For additional data also the weight of the swollen adhesive after solvent removal were recorded.

The need of at least 10mg of material for a distinguishable result meant that statistical testing would not be possible since there was not enough material for that and no time for ageing a new set. Weighting was done with a Radwag AS 220/C/2 analytical balance with accuracy to the fourth decimal.

Comparing the results of swollen and dried residues from the chart underneath to the empirical results from the facing removals, only half the results correlate. Some percentage results for the swelling even are outrageously high.

Comparing the results of swollen and dried residues from the chart underneath to the empirical results from the facing removals, only half the results correlate. Some percentage results for the swelling even are outrageously high.

[160] Freeze-drying was done by Phil Howard, Conservation Department National Museums of Scotland in Edinburgh - 2008

Results of Solubility Testing

Sample	Weight % before	Difference swelling unaged %	Difference swelling aged %	Difference freeze-dried unaged %	Difference freeze-dried aged %	Correlation to facing removal
Gelatine	100	280	593	77	70	Yes
Isinglass	100	364	1615	51	94	No
Rabbitskin	100	259	462	58	92	No
Funori 1.5%	100	3144	2222	75	84	Yes
Funori 2%	100	3627	1473	85	93	Yes
JunFunori	100	3860	1774	96	98	Yes
Fun/Gel	100	1149	1261	76	79	Yes
Fun/Isin	100	1553	1596	85	84	Yes
SeaGel	100	373	276	56	68	Yes
Methocel 1%	100	1657	4067	93	75	No
Methocel 1.5%	100	2288	1999	93	98	Yes
Klucel E	100	413	407	89	79	No
Klucel G	100	651	1076	94	91	No
Blanose 1%	100	2151	1489	71	80	Yes
Blanose 1.5%	100	1988	1475	86	73	No
Tylose	100	1606	3943	86	94	Yes
Aquazol 200	100	193	413	78	67	No
Aquazol 500	100	448	426	90	76	No
Aquazol 50 IMS	100	222	241	78	93	Yes
Aquazol 200 IMS	100	238	351	83	98	Yes
Aquazol 500 IMS	100	381	363	98	93	No
BEVA 371	100	238	270	114	91	No
LMC	100	505	644	96	93	Yes
Mowilith DMC2	100	206	247	89	63	Yes

As can be seen the results of the solubility testing are totally inconclusive and therefore cannot be included into the overall results.

6. DISCUSSION AND CONCLUSION

6.1 RESEARCH RESULTS

The literature research has revealed that different fields in conservation tend to stick to certain types of facing adhesives, for example paintings conservation generally prefers protein glues synthetic adhesives such as BEVA 371, while in paper conservation mainly cellulose ethers and Funori are used. Since facings might be problematic research always tries to find ways of developing new materials such as the volatile adhesives, which reduce the amount of mechanical stress and wetting necessary. The alternativeis to avoid facings altogether. There are international differences as to how quickly new methods are taken up, for instance while the volatile adhesives are much more known and used in German speaking countries, in Britain conservators still seem to be wary about them. On the other hand British and American conservation will often more readily use synthetic materials.

Facing tissues in general use tend towards different types of Japanese tissue, especially the pure kozo ones, but also Eltoline and lens tissue. Depending on the strength a facing needs to have, sometimes non-woven tissues or textiles are preferred. These choices were mainly established by extensive testing and depend on the availability and surface situation.

A much more varied approach is taken toward consolidation adhesives for natural and synthetic matte paints due to the paints' inherent problems with gloss and saturation. Solutions range from the application of traditional adhesives with ultrasonic misters to applications through facing tissue to the research into new synthetic adhesives. Matte paint consolidation has been identified as an important subject since more and more modern artists are using matte effects like underbound pigments in their art work, not to mention the vast amount size-tempera painted wood and ethnographical art.

The practical research has been based on the potential of the identified materials as being used as facing or consolidant, it has also considered the performance of adhesives in terms of both aesthetic and technical criteria. Practical testing and accelerated ageing, adapted to Scottish climate conditions, was used to evaluate the application and ageing characteristics.

It was considered important to keep the testing close to the practical application in order to make the findings more applicable; in hindsight this proved useful, since it became evident after evaluation that the results on different materials produced varying results. Adhesives for example,

which showed a questionable performance as a pure film, on paper or on size-tempera replicas, would do well on the original paint surfaces.
Results generally conformed to previous published studies about most of the adhesives, apart from a few that differed in some factors when considering discolouration and reversibility.

The testing identified several adhesives that would possibly perform best as short-term, long-term or consolidation adhesive, although the testing was not as complete as hoped due to the tight time-frame and technical problems. Pressure-sensitive adhesives, Paraloid B72 and sodium alginate on the other hand were considered unsuitable for size-tempera after the preliminary testing. Overall performance is detailed in the following discussion and the chart on the next page. The final choice of adhesives has been made specifically with Scottish size-tempera on wood and its surrounding climate in mind, however different options could prove more useful for other types of matte paint or pigments in different climates.

Concerning the facing tissues a specific choice cannot be given, because after testing it became clear that many of the deciding performance factors for Japanese tissue, Eltoline, lens or synthetic tissue are indeed personal choices for specific situations.

Unfortunately, in the remit of this research it has not been possible to identify a suitable way to circumvent the use of facing adhesives altogether.

	Both Surfaces		Original Paint Surface								Replica Paint Surface					On Paper			
	Application		Facings		Surface changes		pH				Facings			Surface changes		Tensile Testing		Surface Change	
	General	Viscosity	adhesion on aged surface	Removal	Gloss	Colour	liquid adhesive	dried adhesive	aged adhesive	paint surface aged	Strong Pigment Influence on Facing Removal	adhesion on aged surface	Removal	Gloss	Colour	unaged	aged	Gloss	Colour
Gelatine 2.5% reference	(++)	(++)	(++/+)	(+/-)	(++)	(++)	5.7	5.61	5.65	6.55	G, A, I, U	(++)	(o)	(++)	(+/-)	(++)	(++)	(++)	(++)
Isinglass 2%	(++)	(++)	(+)	(+)	(++)	(++)	6.9	5.74	6.78	6.43	G, A, I, U	(++)	(o)	(++)	(++/+)	(++)	(++)	(++)	(++)
Rabbitskin Glue 2%	(++)	(++)	(+)	(+)	(++)	(++)	6.07	5.60	5.29	6.23	G, A, I, U	(++)	(-)	(++)	(+)	(+)	(++)	(++)	(++)
Funori 2%	(++)	(++)	(++)	(++)	(++)	(++)	6.73	6.92	8.00	6.58	(G)	(++)	(++)	(++)	(++)	(+)	(++)	(++)	(++)
Funori 1.5%	(++)	(++)	(++)	(++)	(++)	(++)	6.9	6.90	8.35	6.45	(G, U)	(++)	(++)	(++)	(++)	(+)	(++)	(++)	(++)
JunFunori 1.5%	(-)	(-)	(++)	(++)	(++)	(++)	7.11	7.12	7.97	6.58	(A, U)	(++)	(++)	(++)	(++/+)	(+)	(++)	(++)	(++/+)
Funori 2% / Gelatine 2% 1:1	(++)	(++)	(++)	(+)	(++)	(++)	6.85	6.19	6.44	6.50	A, I, U	(++)	(++)	(++)	(++/+)	(+)	(++)	(++)	(++)
Funori 2% / Isinglass 2% 1:1	(++)	(++)	(++)	(-/o)	(++)	(++)	7	6.12	7.18	6.41	R, G, I, U	(++)	(oo)	(++)	(++/+)	(++)	(+)	(++)	(++)
SeaGel 100%	(++)	(++)	(oo)	(++)	(+)	(-)	7.14	6.38	6.42	6.59		(oo)	(++)	(+)	(+/-)	(+)	(o)	(++)	(-)
Methocel A4C 1.5%	(-)	(-)	(-)	(++)	(++)	(++)	6,94	6.28	7.27	6.43	(U)	(++)	(++)	(++)	(+)	(++)	(+)	(++)	(++)
Methocel A4C 1%	(+)	(+)	(+)	(++)	(++)	(++)	6.03	6.90	7.77	6.52	(U)	(++)	(++)	(++)	(+)	(+)	(+)	(++)	(++)
Klucel E 5%	(++)	(++)	(oo)	(++)	(+)	(+/-)	6.75	6.70	7.43	6.56	(A, G, I)	(++)	(++)	(+)	(-)	(o)	(o)	(++)	(++)
Klucel G 1.5%	(+)	(+)	(oo)	(++)	(++)	(++)	7,24	7.19	8.16	6.57	(A, G, I)	(++)	(++)	(++)	(++/+)	(-)	(o)	(++)	(++)
Blanose 7M8SF 1.5%	(+)	(+)	(-)	(++)	(+)	(++)	7,32	7.18	7.61	6.42		(++)	(++)	(+)	(+)	(++)	(++)	(++)	(++)
Blanose 7M8SF 1%	(+)	(+)	(+)	(+/-)	(+)	(++)	7.4	7.20	7.49	6.65		(++)	(++)	(+)	(++/+)	(++)	(+)	(++)	(++)
Tylose MH300 1%	(+)	(+)	(+)	(++)	(++)	(++)	6.94	7.49	7.64	6.55	G, A, U	(++)	(++)	(++)	(++/+)	(++)	(+)	(++)	(++)
Aquazol 200 8%	(++)	(++)	(o)	(++)	(+)	(+)	6.22	7.13	7.37	6.53		(++)	(++)	(+/-)	(+)	(++)	(+)	(++)	(++)
Aquazol 500 5%	(+)	(+)	(-/o)	(++)	(+)	(+)	6.33	7.37	7.82	6.36		(++)	(++)	(+/-)	(++)	(+)	(+)	(++)	(++)
Aquazol 50 10% IMS	(++)	(++)	(o)	(++)	(+)	(+/-)	5.59	7.31	7.35	6.41		(+)	(++)	(-)	(+/-)			(++)	(++)
Aquazol 200 10% IMS	(++)	(++)	(-/o)	(++)	(++)	(+/-)	5.65	7.09	7.17	6.28		(+)	(++)	(-)	(-)			(++)	(++)
Aquazol 500 7% IMS	(+)	(+)	(-/o)	(++)	(++)	(+/-)	5.81	7.19	7.14	6.41		(+)	(++)	(-)	(+/-)			(++)	(++)
BEVA 371 Lascaux thin foil																(+)	(+)		
BEVA 371 30%	(+) solvent!	(++)	(+)	(+)	(++)	(+/-)	4.94	5.83	5.80	6.72	(O)	(++)	(+)	(++)	(+/-)			(++)	(-/o)
LMC 100%	(++)	(++)	(++)	(oo)	(-)	(-/o)	8.02	5.43	5.68	6.68	A, U, B, (rest)	(++)	(oo)	(-)	(oo)	(-)	(++)	(++/+)	(o)
Mowilith DMC2 20%	(++)	(++)	(++)	(-)	(-)	(+/-)	4.2	5.93	5.45	6.44		(++)	(o)	(-)	(-/-)	(-)	(+)	(++)	(+/-)
Cyclododecane dissolved	(-) brush!	(++)	(o) sublimated	n/a	(+)	(++)		7.28	n/a	6.61		(o) sublimated	n/a	(+)	(++)			(++)	(++)
Cyclododecane melt	(+) brush!	(+)	(++) sublimated	n/a	(++)	(++)		7.25	n/a	6.71		(++) sublimated	n/a	(++)	(++)			(++)	(++)
Menthol melt	(+) brush!	(+)	(++) sublimated	n/a	(++)	(++)		7.27	n/a	6.44		(++) sublimated	n/a	(++)	(++)			(++)	(++)

Performance Grading: (++) very good, (+) good, (-) medium, (o) poor, (oo) unsuitable

Pigment Code: W chalk white, O goldochre, R ironoxide red, G green, A azurite, I indigo, U raw umber, B ironoxide black

6.2 DISCUSSION OF TEST RESULTS

For understanding the relevance of these results, it is important to understand that accelerated ageing cannot be equivalent to decades of natural ageing. It produces more intense reactions due to its more extreme nature, thus giving only an indication which adhesive may first fail the set benchmarks under comparable circumstances. These results are indicators of what could happen, showing possible dangers and weaknesses and cannot necessarily determine what will happen over 25, 50 or 100 years of natural ageing, since this incorporates too many factors that cannot be recreated in a laboratory. Nevertheless, knowing potential risks and weaknesses of aged adhesives helps in deciding which would be most useful under the circumstances, it can also eliminate those that could pose problems in the short term or future for the paint layer.

To gain an overview of the adhesives' performance the data from the testing is assembled in a chart.

Looking at the application, it is evident that almost all adhesives in their chosen concentration are easy to apply and are of appropriate viscosity to penetrate the tissues. JunFunori 1.5% and Methocel A4C 1.5% were an exception being very viscous at that concentration necessitating increased brushing for application. The dissolved cyclododecane was problematic during film formation, because the powdery, crystalline film would re-dissolve immediately on repeated application making a thick, uniform formation nearly impossible.

Comparing the facings after ageing on the original paint surfaces and on the replicated ones, differences became apparent, suggesting that using replicas instead of original material does not necessarily produce results applicable to the original.
The replicas show less denaturation in their binding medium, which adds its adhesive strength to that of the facing adhesive, making for a stronger facing adhesion. Facings on the replicas still adhered very well after ageing, apart from the SeaGel facing, which had fallen off due to the total failure of the adhesive. On the other hand the facings on the original panels showed stronger signs of failure in form of ripples and pronounced delamination; SeaGel, Klucel E, Klucel G, Aquazol 200 and Aquazol 50 IMS being complete failures. Strong delamination was observed with Methocel A4C 1%, Blanose 7M8SF 1.5%, Aquazol 500 5%, Aquazol 200 10% IMS, and Aquazol 500 7% IMS. Only Funori and JunFunori were still able to hold the tissue flush to the paint surface.

When removing the facing the same tendencies can be found on both original and replica, however the results are much more pronounced on the replica. While gelatine and Funori/isinglass facings became more difficult to remove, taking a visible amount of paint flakes with them, on the replicas these protein glues damaged the azurite, indigo, green and raw umber sample stripes to the point where the indigo and green stripes stuck completely to the facing, and azurite and raw umber partially. Rabbitskin glue was slightly less damaging and the Funori/isinglass mix on the other hand was the least successful. The four mentioned pigments also caused reduced solubility in most other adhesives, indicating that their chemical structure promotes reactions with adhesives. This supports findings by Fiedler that pigments can cause a significant decrease in solubility.[161] According to that study and that of Schilling[162] proteinacious materials are influenced by certain pigments as their reactive hydrophilic amino acids react with the pigment, decreasing solubility as these groups are no longer available. The differences in the amounts of those amino acids in each protein glue[163], and the availability of hydrophilic groups, could account for variations in solubility.
A reason why the indigo in the original paint layer seems to pose less of a problem might be that any reactive groups in the pigment have already reacted a long time ago with the original binding medium, making aged indigo less prone to reactions.

Comparing the tensile testing results of facing removal it is evident that although aging and cross-linking in the adhesives increased their tensile strength especially in the case of BEVA the facings still had the tendency to fail before any damage could be done to the paint layer. This failure seems to have its source in reduction in plasticity, because the flexibility of the adhesives hardly changed at all. The adhesives with low tensile strength and plasticity were also the ones where facings delaminated the most, namely SeaGel, Klucel E and Klucel G. The significant failure of Aquazol in IMS may have been caused by an inherent change in tensile properties or by its greater penetration into the porous original paint layer.

Eltoline tissue facings show slightly less pronounced rippling than Japanese Kozo tissue. This may be because, although the Japanese tissue has greater wet strength an advantage for consolidation facings and facing removal, the Eltoline facing is more flexible than plastic.

[161] Fiedler (2001), p. 56
[162] Schilling, Khanjian (1996), pp. 127/128, 138
[163] Schilling, Khanjian (1996), p.141

During facing removal the Japanese tissue was far more resistant to mechanical stress, making it easier to remove difficult facings. This was most obvious in combination with the Lascaux Medium, which needed extensive rewetting and rubbing to take the tissue off. While the Japanese tissues stayed mostly in one piece, the Eltoline tore to the point were numerous residues had to be removed separately from the paint layer with increased mechanical action.

Another criterion was the optical changes that residues of a facing adhesive may cause to a paint surface.

Reviewing the results on the test samples it becomes obvious that gloss is a minor problem with very porous surfaces like old paint layers and paper. On the paper samples no discernible gloss could be detected, but the old paint layer became glossier with Lascaux Medium and Mowilith. The replica paint surface was more susceptible to gloss, adding Aquazol, especially in IMS, to the group of more unsuitable adhesives. It was notable that certain pigments retained less gloss than others, as more porous pigments like chalk and ochre absorbed more facing adhesive from the surface. The more pronounced gloss on the replicas is possibly due to the less denaturated binder, which prevents absorption of too much facing adhesive. One problem with IMS application is that it evaporates faster than Aquazol can be absorbed into the paint layer, leaving a greater amount on the surface.

Darkening of the paint layer is a sign of stronger adhesive saturation in a porous paint, which again seemed to depend on a pigment’s absorption ability as observable on the replicas. Generally the synthetic adhesives were most problematic on the original paint layer causing surface saturation because they did not penetrate too deeply into the paint layer. Discolouration could not be detected by optical evaluation. Poorest among the tested adhesives for darkening were again Lascaux Medium and Mowilith. The colorimetry showed that darkening was the case for most adhesives, dependant on the pigment type, accounting for a great part of ΔE^*ab. The second biggest influence was the amount of yellowing. Comparing all ageing performances by the overall value for colour difference, ΔE^*ab, for each pigment stripe Lascaux Medium is unsuitable, while gelatine, SeaGel, Klucel E, Aquazol in IMS, BEVA and Mowilith can cause readily perceptible colour changes. On paper samples, only SeaGel, BEVA, Lascaux Medium and Mowilith showed a distinct change. Discolouration also of other adhesives had been pronounced after the UV-ageing and often reverted to a lower discolouration after climate ageing. This could be due to free radicals that are created by UV-light and react with polymers. Radicals can change the chain lengths and bond conjugations, resulting in discolouration. The addition of water during

the climate ageing on the other hand can result in the formation of peroxy radicals, which have a bleaching effect, thus reducing the discolouration again.
After performing colorimetry it became evident that the surface an adhesive is applied to influences the degree of discolouration. As can be seen from the charts in chapter 5.5.2 the discolouration on the paper samples differs from the one on the replicas. Observation of the differently discoloured pure adhesive film added to this conclusion.

The results from the pH testing were encouraging, even though the pH of some adhesives were not ideal in liquid or aged form. The original paint surface reverted to a 'comfortable' pH of 6-7 for all adhesives and neither the original nor the replicated paint layer showed any damage that could be attributed to the pH. A comparable reversal to a pre-treatment pH could be observed during the conservation of a painted ceiling with gelatine where the paint surface became slightly more acidic just after treatment, but settled back to pre-treatment values four days later. This indicates that the ageing processes are probably not the influential force behind this 'buffering' effect.
Therefore, it can be assumed that even though the tested pure adhesives on their own have critical pH-values or change them during ageing, this is of no discernible consequence for this specific type of paint layer, since the pH will balance in the 'comfort zone' again after application and remain there. But during the drying period of an adhesive the pH difference may promote reaction between original materials and the consolidant or facing adhesive.

6.3 PRACTICAL IMPLICATIONS

Considering the performances of all adhesives in the different testing sequences it becomes clear that acrylic emulsions and solvent based acrylates are generally not suitable as facing adhesives for these substrates, because of poor removability, effects on gloss and discolouration. Although Lascaux Medium for Consolidation was designed for matte paint layers similar to the painted wooden interiors in Scotland, it would be best suitable as a consolidant when applied underneath flakes without leaving residues on the surface. As a facing adhesive and consolidant through facings it is unsuitable. BEVA 371 on the other hand would be suitable under certain circumstances and on the right pigments. It has been used successfully on a board and beam ceiling in the Historic Scotland estate, where it accorded with previous treatments. Another disadvantage would be the restriction to non-aqueous adhesives after BEVA treatment, although they should discourage microbiological attack.

As a facing adhesive, volatile adhesives perform well and the melts are suitable despite possible problems with the application method. The addition of a facing tissue helps to reduce the sublimation time and improve surface protection, especially in situations where paint flakes could easily be dislodged when the supporting adhesive sublimates. Their limited staying time makes them best suitable for transport or short-term application. Long-term application to an upside-down surface might still result in losses. If left unmonitored, part of the layers might sublimate faster than the rest, leaving loose paint flakes unsupported again. Using a facing tissue would not be helpful either, because loose flakes might be obscured and consequently become lost on tissue removal.

The Aquazol's performance depends mainly on the chain lengths and solvents used. Its major problem is poor facing adhesion and darkening. However, the facing adhesion and ageing characteristics of the water-bound adhesive are slightly better than of the IMS-bound one. Aquazol 200 8% could prove suitable under the right circumstances and on the right pigments. Since all Aquazol types are soluble in a wide range of solvents outside the tested ones, trials with another slow evaporating solvent might yield better results concerning gloss, darkening and facing adhesion.

Of the cellulose ethers both Klucel types are unsuitable because of darkening and poor facing adhesion. Of the remaining ones Methocel A4C 1%, Blanose 7M8SF 1% and Tylose MH300 1% are preferable, showing the strongest facing adhesion and the least surface changes, although consideration has to be given to pigment influences on reversibility. They also might be suitable as consolidant, applied through a facing and as previously mentioned they have been noted to reduce microbiological attack.

Among the natural adhesives Funori and JunFunori showed the best overall performance of all adhesives along with the volatile adhesives, although they are considered to be 'weak' adhesives. They also have the added advantage of being considered less susceptible to microbiological attack than the protein glues. After ageing their facings were the only ones that were still flush with the surface on all test substrates and there is no gloss, discolouration or darkening. The only discernible change was that the original paint layer became slightly lighter – perhaps due to a cleaning effect. Even though slightly alkaline in pure form, this seemed to have no influence on the original paint layer, which stayed between pH6 and pH7. The JunFunori performed as well as natural Funori, but was more difficult in application due to its viscosity and low penetration. Consideration has to be given to the influence of pigments on solubility and appearance of the paint layer. Whether both adhesives are strong enough to work as a consolidant as well would need to be tested in the field.

The protein glues appear to perform less well mainly due to their bad performance on the replicas. Of the three, gelatine seems to have a problem with re-solubility while rabbitskin glue has slightly more favourable ageing characteristics than isinglass, which under the right circumstances can be equally problematic as gelatine. The Funori/isinglass mixture is unsuitable due to its poor removability characteristics, but the Funori/gelatine mixture could be used, although it might be more suitable as a consolidant applied through a facing. Comparing the performance of gelatine to those of the other adhesives, it was not the worst choice to be used apart from the re-solubility problem as it generally keeps the paint layers intact and mostly unchanged over a long time as a consolidant.

Considering the facing tissues, not much difference could be found, apart from greater wet strength in the Japanese tissue, which is very helpful, if the facing is difficult to remove.

6.4 CASE RELATED RECOMMENDATIONS

From the tested adhesives Funori (1.5% / 2%) and JunFunori 1.5% would be best suited for long-term facings, especially on installed walls and ceilings; they perform exceptionally well and are readily removable after accelerated ageing , although JunFunori is slightly more difficult to apply due to its high viscosity. After removal no tide lines were visible and the only evidence of treatment was a very slight increase in brightness, leaving the paint surface appearance as it was supposed to look. It is said not to encourage microbiological attack and seems to pose no threat concerning pH changes. Aqueous treatments are possible after the application of both adhesives.

As facing adhesives for short-term transport and storage, volatile adhesives in form of melts could be more beneficial, despite the added care needed to apply them. Cyclododecane and menthol both left no visible evidence of having been applied on any test surface, indeed the sublimation time is prolonged with the use of facing tissue. Menthol might pose difficulties in badly ventilated areas due to its strong odour and it was not possible to test for remaining essential oils.

For transport the cyclododecane melt would provide a thick, waxy layer that can also protect tented paint flakes from abrasion and damage. Due to its sublimation process the time it stays on the surface is limited to the thickness of its layer, mostly weeks to a few months. To be applicable as long-term protection sublimation it could be inhibited by covering the layer with a non-breathable material or adhesive cover layer, for example a cellulose ether.[164] This method has not been tested.

If an adhesive is chosen as a consolidant to be applied through a facing tissue, apart from gelatine and isinglass the cellulose ethers Methocel A4C 1%, Blanose 7M8SF 1% and Tylose MH300 1% would possibly be a good choice. An advantage of the protein glues over the cellulose ethers would be the greater simultaneous cleaning effect. It has to be noted though that the adhesives' ageing performance has not been tested as a consolidant only and the choice has been based on experiences in the field and their performance as facing adhesive.

Based on this research the Funori/isinglass mixture, SeaGel, Klucel E /G, the synthetic adhesives Aquazol in IMS, Lascaux Medium for Consolidation and Mowilith DMC2 were considered unsuitable for above named applications on size-tempera paint.

6.5 FUTURE RESEARCH

Due to the limited time frame the research could not address solubility other than in an empirical way during facing removal. It would be advisable to do scientifically reproducible results independently from the results obtained on original and replica paint layers for better comparisons.

Further testing would also be required in the form of examination of cross-sections for adhesive penetration and retention, especially considering the volatile adhesives that could become trapped underneath consolidants if not totally sublimated from the depths of the paint layer.

In these cases this research would possibly have to be extended to cover not only this aspect, but also a more practical application method than brushing them onto extensive surfaces. It would

[164] Brückle *et all*. (1990)

also be of interest to identify suitable retention methods if volatile adhesives are applied as a long-term facing.

Keeping in mind the problematic issues about facings as well as the reasons why they sometimes cannot be avoided, further research could be directed into finding ways to remove the adhesive completely from the facing matrix.

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Historic Scotland Property Records

The following archive records have been used for this work:

Aberdour (HSCC_C_600_SP)

Crathes Castle (XHSCC_O_1015_HD)

Culross Palace (XHSCC_O_1165_SP)

Gladstone's Land (XHSCC_O_1272_SP)

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310 Lawnmarket (XHSCC_O_1595_SP)

Moubray House (XHSCC_O_1473_SP)

Northfield (XHSCC_O_1504_SP)

Prestongrange House (XHSCC_O_1549_SP)

Riddle's Court, Lawnmarket (XHSCC_O_1565_SP)

St. Mary's Grantully (HSCC_C_675_SP)

10. Appendix CD

Historic Scotland Technical Papers

Available at www.historic-scotland.gov.uk/technicalpapers

1 Thermal performance of traditional windows

2 In situ U-value measurements in traditional buildings - Preliminary results

3 Energy modelling analysis of a traditionally built Scottish tenement flat

4 Energy modelling in traditional Scottish Houses (EMITSH)

5 Energy modelling of a mid 19th century villa

6 Indoor air quality and energy efficiency in traditional buildings

7 Embodied energy in natural building stone in Scotland

8 Energy modelling of the Garden Bothy, Dumfries House

9 Slim-profile double glazing - Thermal performance and embodied energy

10 U-values and traditional buildings - In situ measurements and their comparison to calculated values

11 Scottish Renaissance interiors: Facings and adhesives for size-tempera painted wood

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