CONSOLIDATING DISTEMPER PAINT
- REVIEWING THE SUITABILITY OF STURGEON GLUE

Anne Apalnes Ørnhøi*, Tone Marie Olstad*, and Nina Kjølsen Jernæs*
*Norwegian Institute for Cultural Heritage Research (NIKU), Oslo, Norway.

Abstract

For the last three decades, sturgeon glue has been the preferred consolidation agent for the treatment of distemper decorative paintings in Norwegian stave churches. However, in the last decade, reflaking has been discovered after just a brief period of time. This qualitative research-based paper aims to describe and clarify why the use of sturgeon glue is unsuccessful in some areas and highly successful in others. The characteristics of distemper paint, sturgeon glue as a consolidation agent, relevant parameters, analyses and practical applications are discussed. The results show that sturgeon glue does not penetrate beyond the top layers of the paint structure, resulting in flaking of paint in distemper decorative paintings with several paint layers and a thicker structure.

Keywords:

Distemper paint, sturgeon glue, matte paint, consolidation, stave churches.

Introduction

Since the early 1990s, sturgeon glue has been the dominant consolidation agent for distemper decorative paintings in churches and secular buildings in Norway. However, during the last decade, conservators at The Norwegian Institute for Cultural Heritage (NIKU)[1] have found that sturgeon glue does not always give the expected result; the consolidation might not be instantly successful, or the distemper paint treated with sturgeon glue may begin to flake after just a few years. This became especially apparent when the Norwegian Directorate for Cultural Heritage's Stave Church Preservation Programme, 2002–2015, evaluated the conservation work within the programme in 2013–2014. NOK 25 million of the 130 million allocated to the programme had been spent on church art, including consolidation of distemper decorative paint (Bakken 2016:15). Failure of the consolidation of distemper decorative paint in five of the twelve stave churches[2] during the programme were revealed. This unfortunate result boosted the research work on distemper paint and consolidation at NIKU.

This paper is an outcome of NIKU's ongoing research on sturgeon glue and consolidation - a research assignment given to NIKU by the Directorate in 2014 after the survey concluding the Stave Church Preservation Programme[3]. Based on experience and research, the paper seeks to determine why sturgeon glue does not always give the expected result, in which cases sturgeon glue is the best choice and when an alternative consolidation agent should be used.

The challenges of consolidating distemper paint are multifaceted and, alongside other conservation tasks, have been studied over many years. The current article

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mirrors this long-lasting project, which is ongoing, by introducing the characteristics of distemper paint as well as distemper decorative paint in stave churches, consolidation remedies and, more specifically, sturgeon glue. Furthermore, the article presents analyses of consolidated distemper paint as well as other practical aspects when evaluating conservation materials and methods. Subsequently, the article presents the results and a discussion before concluding.

Distemper paint

Distemper paint is characterised by a porous, usually matte, surface. It is a water-based paint made from pigment with animal glue as its main binder. The types of glue, and other possible ingredients in the binder, vary according to what was available at the time and, in particular, what the individual painter preferred to use. The ratio of binder to pigment in the distemper paint must be prepared in such a way that the paint neither runs down the wall while wet, nor rubs off after drying. Different pigments require different binder ratios. If the proportion of glue is too high, the paint layer could delaminate from the substrate, either immediately after drying or after years of fluctuating climatic conditions.

Due to the water-based binder, the most common cause of damage to distemper paint is moisture and water, which wash the paint off or leave pale, washed-out patches in the paint layer where the binder is weak or missing. Based on experience, dark stains along the outer edges of the pale patches affected by water and dampness are assumed to be concentrations of glue and dirt, pigment particles and water-soluble extracts from the wood. NIKU has often observed a 'washed-out' binder in unheated churches in humid climates. Fluctuating levels of high relative humidity can lead to the binder becoming weak (Schellmann 2007: 62). Unstable climatic conditions, a common problem in heated buildings with lower relative humidity, lead to flaking and blistering of paint layers of a certain thickness. Direct contact and unintentional friction against the surface from the clothes or hands of visitors change the surface lustre and appearance or cause the paint to wear off completely.

Figure 1. Example of distemper decorative painting in Nore stave church. Photo: Nina Kjølsen Jernæs, NIKU, 2020.

Characteristics of distemper paint in Norwegian churches

Distemper paintings from the seventeenth and eighteenth centuries are found in about sixty-five churches in Norway, including nineteen of the twenty-eight preserved stave churches, and in secular buildings inland and along the coast (Olstad and Kaun 2011). Distemper paintings are typically dominated by tendrils and vines, less commonly by figures and landscapes, and often cover the entirety of the walls or interiors. Distemper paintings are modelled on originals from countries in continental Europe and are a forerunner of Norwegian folk art painting (Aubert 1902). The artistic and cultural importance of these paintings has varied over the centuries, and they have not always been regarded as worth preserving. Beginning in the twentieth century, they were viewed as an imitation of costlier materials, such as tapestries and gilded-leather wall coverings. Subsequently, these paintings were assigned increased cultural and historic value by art historians, cultural heritage managers and artists (Olstad 2016).

Consolidating distemper paint – materials

The aim of consolidation is to add a supplemental binder to the paint structure and to consolidate flaking paint. The challenge of consolidating matte, water-soluble paint is to find a consolidation substance that binds flaking paint and strengthens the paint layer without saturating the structure in such a way that it changes the appearance of the artwork. The consolidation agent must have similar mechanical characteristics as the original glue or binder, and it must be possible to apply it without disturbing the

Figure 2: Distemper decorative painting in Uvdal stave church. Photo: Anne Apalnes Ørnhøi, NIKU, 2014.

paint layer. In addition, it must decompose without causing undesired effects and in such a way that reconsolidation is possible (Hansen et al. 1994).

Various conservation methods and materials were used in Norway from the 1930s to the 1970s, including gelatine, rabbit glue, casein, beeswax and linseed oil as well as soluble nylon. The latter was regarded as a promising consolidating agent for distemper paint, until its instability was discovered (Solberg and Olstad 1994; Sease 1981; de Witte 1975).

Since the mid-1980s, the conservation of distemper decorative paintings has been a priority of the Norwegian Directorate for Cultural Heritage. For painting conservators (at the Directorate until 1994 and thereafter at NIKU), it has been a continuous challenge to develop an optimum and applicable consolidation method for these fragile matte paintings. In 1992, extensive testing of different consolidation agents for distemper decorative paintings was undertaken as part of conservation work in Uvdal stave church. In addition to sturgeon glue, Paraloid B72, Klucel EF, Klucel L and Plextol B500 were tested. Klucel EF, Klucel F and Plextol B500 changed the surface appearance, darkening the surface. Paraloid B72 did not change the surface appearance, but like the others it was dissolved in solvents, which is not a good option for conservators or the public when consolidating large areas. The tests favoured sturgeon glue, which did not change the surface appearance and dissolved in water. Thus, sturgeon glue became the preferred consolidation material for distemper paint in Norway (Olstad 1992; Solberg and Olstad 1994).

Different methods of application of sturgeon glue were also explored. Application directly on the paint surface with a brush, application using Japanese tissue, spraying, the use of solvents before the consolidation material as well as solutions with different concentrations and temperatures were tried and assessed to find the most suitable method of application - a standard method that could be adjusted to the actual painting and situation.

Figure 3. Consolidating distemper decorative painting with sturgeon glue in Ringebu stave church. Photo: Anne Apalnes Ørnhøi, NIKU, 2010.

Consolidating distemper paintings in stave churches

Since 1992, fifteen distemper decorative paintings in fourteen stave churches have been consolidated with sturgeon glue (Olstad 2016:77). Twelve of these consolidation campaigns were part of the Stave Church Preservation Programme (2002–2015). The consolidation was executed using a 2–3% solution of sturgeon glue in water. This was applied with brushes through Japanese tissue paper in small areas in a continuous process. A stop could only be made at the end of a board or a black line in the painting to avoid visible 'tidelines' from the water-based consolidation agent. Absorbent paper was placed on top of the tissue, and pressure was applied using hands or small paint rollers. The critical stages of the process were allowing time for the glue to soak in, applying sufficient pressure, taking off the paper while it and the paint were still wet and ensuring that all glue on the surface was lifted off.

Sturgeon glue, from medical use to consolidation agent

Sturgeon glue has been known and used through the ages. It is made from the inner membrane of the air bladder of the sturgeon fish (Petukhova and Bonadies 1993). In classical antiquity, sturgeon glue was appreciated for its medical and cosmetic uses. According to handbooks of medicine and pharmacology, it was used as ingredient into the twentieth century (Scarborough 2015). Late Medieval illuminators applied sturgeon glue when gluing powdered gold to manuscript pages. Theophilus described how to prepare it: 'Then take the bladder of the fish, known as the sturgeon, wash it three times in lukewarm water, cut it into pieces and, putting in a very small pot with water, allow it to soften overnight. In the morning, heat it over a fire without letting it boil, until you test with your fingers to see if they stick together. When they stick firmly together, it is a good glue' (Scarborough 2015: 58). With some modifications, sturgeon glue is made in the same way today. Sturgeon glue has been on the market constantly, but not everywhere or for everyone. It is not known when or where it was added to the conservators' toolbox for the first time. To the best of our knowledge, Russian conservators were among the first to use sturgeon glue for consolidation. Conservator Tamara Chizhova at the Hermitage in St. Petersburg described the use of sturgeon glue at the museum since the end of the 1950s (Chizhova 1981). As a consolidation agent for distemper paint, sturgeon glue is dissolved in water. It changes the visual appearance of the distemper paintings less than other consolidation agents. It is an organic adhesive substance that decomposes in the same way as the original binder and has a high degree of adhesion at low concentrations and excellent penetration properties.

A literature search showed that few studies have considered sturgeon glue as a consolidation material, and even fewer have examined the consolidation of matte and porous paint in general. The collected literature shows that research on sturgeon glue is generally limited to Europe and North America. It does not appear to be used widely in other parts of the world, or the information has been published in languages other than English. Research on the topic is largely focused on by individuals and has not given much attention at the institutional level.

Peer-reviewed articles have focused on testing the consolidation materials rather than on descriptions of use. This information is probably described in treatment reports from different institutions, which could not be collected in the literature search. However, the review gave us an indication of other consolidation materials that are used internationally and/or have been tested for porous and matte paints, such as methyl cellulose (Soppa and Lechenne 2017; Gautier 2017), hydroxypropyl cellulose and gelatine (Gautier, 2017) and Funori/JunFunori (Michel, 2011).

Research methods: Finding answers to a practical challenge

This study is qualitative in nature and the research methods were selected as a practical way of attacking the challenge of understanding the cases in which sturgeon glue fails and why. The different methods addressed different challenges related to the distemper paint system and the consolidation treatment of distemper paint.

First, the present status and method of consolidation for distemper decorative paintings were investigated. Second, relevant parameters for comparing paintings were defined, and a course was held on making and painting with distemper paint. Finally, multiple analyses of paint samples were conducted.

Table 1. Information collected from the six selected stave churches.

Stave church	Over painted	Consolidated with sturgeon glue	Flaking paint after 2013	Thick/thin paint layer	Former treatments (before 1990)	Heated/not heated church
Uvdal		1993		Thin	X	Not heated
Nore		1994–1995, 2004–2006	X (Some)[5]	Thin (some areas thick)		Not heated
Eidsborg		2007	X (Some)	Thin (some areas thick)	X	Heated
Flesberg	X	2008	X (Some)	Thick (some areas thin)		Heated
Heddal	X	2010	X	Thick	X	Heated
Ringebu	X	2012	X	Thick		Heated

Overview of the conditions and method of consolidation

The information collected for each of the paintings was based on treatment and condition reports, interviews with the project leader of the conservation campaign and on-site examination of the paintings to review the present condition. The intention was to gather detailed information about the state of preservation of the distemper decorative paintings to create a foundation for further research.

The condition survey executed in 2013–2014 as part of the Stave Church Preservation Programme revealed that four of the five paintings had flaking paint (Olstad and Ørnhøi 2014). Soon after, flaking paint was also discovered on a fifth example - the paintings in Ringebu stave church.

Hence, the paintings in the five stave churches where flaking paint was discovered along with the one with no flaking paint were selected as cases for further study: Uvdal (no flaking paint), Nore, Eidsborg, Flesberg, Heddal and Ringebu (Table 1).[4]

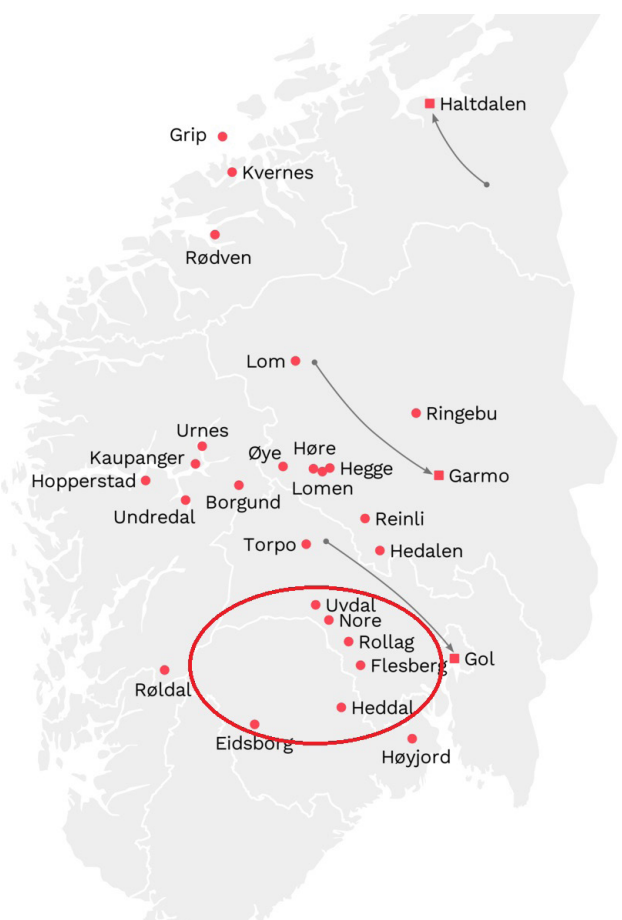

Figure 4. Map of the Norwegian stave churches. Red circle shows the locations of the six stave churches selected for this study. Copyright: Bevarte stavkirker i Norge. Av Store norske leksikon. License: CC BY NC SA 3.0. https://media.snl.no/media/183168/standard_stavkirker-kart.png.

A majority of the distemper decorative paintings in the stave churches have been overpainted (11 of 19). Five of these still have intact overpaint. Of the paintings chosen for our research, three were overpainted: Flesberg, Heddal and Ringebu. In Heddal, a medieval distemper painting was overpainted with seventeenth-century distemper decorative painting, while the painting in Flesberg has a secondary layer of monochrome distemper paint. The paintings in Ringebu are mainly 1921 replicas of eighteenth-century distemper decorative paintings on top of a whitewash that covers the remnants of the original eighteenth-century paint. The overpainted structures were selected to represent the overpainted distemper paintings in the stave churches not included in the Stave Church Preservation Programme survey.

Defining the parameters for comparing the paintings

Relevant parameters were defined to try to find correlations or tendencies between the different conditions of the distemper decorative paintings. Information from the six selected stave churches was compared to determine if any of the parameters were shared by the paintings where the consolidation with sturgeon glue partly failed.

The parameters were as follows:

A. The painting technique, including the application, number of layers, thickness, binding medium and pigments as well as additives to the paint.

B. Past conservation treatments - including overpainting.

C. The consolidation method applied, possible changes in the consolidation method or the 'personal touch' of the conservator. [6]

D. Temperature and relative humidity, both during the conservation campaign as well as the climate in the church throughout the year; heated/unheated or intermittent heated.

E. Frequency of use, which is important both for the climate and the wear and tear of the paintings.

The making of and painting with distemper paint

To obtain more knowledge about the painting technique for parameter A, a course on making and applying distemper paint was held at NIKU. The aim of the course was to understand the observations made of the actual paintings: variations on the surface, the varying ratios between pigment and medium, the degradation based on the choice of pigment and how the painter worked. The two-day course for the conservators at NIKU was led by Professor Emeritus Jon Brænne. The intention was to see if the conservators could imitate the characteristics observed in the aged distemper paintings and to gain practical knowledge.

Analyses of consolidation material

Over the years, NIKU has collaborated with international institutions on several types of analyses to better understand the characteristics of aged distemper paint, the original binding materials and pigments and the technical results of consolidation treatments. After the condition survey concluding the Stave Church Preservation Programme, our main hypothesis regarding the reflaking of paint after treatment with sturgeon glue was that the glue

Figures 5 and 6: Making distemper paint on the course. Photo: Anne Apalnes Ørnhøi, NIKU, 2021.

penetrated too deeply into the structure, beyond the paint and into the wooden support. In 2015, paint samples taken from the distemper decorative paintings in the six selected churches were sent to the Centre for Art Technological Studies and Conservation (CATS) in Copenhagen (CATS 2015). The main aim of the requested analyses was to understand where in the paint structure the sturgeon glue was located following consolidation treatment. However, the analyses did not seem to be sufficiently targeted, and thus additional analyses were performed in 2017 and 2019 at the Department of Conservation and Restoration at Stuttgart Academy of Art and Design, including an enzyme-linked immunosorbent assay (ELISA) and immuno-fluorescence microscopy (IFM) on the same set of samples (Kjølsen Jernæs and Ørnhøi, 2021).

Results and discussion

Overview of the conditions and method of consolidation

Five of the six consolidated paintings had areas with recurring flaking paint when revisited. The condition survey in 2013-2014 showed recurring flaking paint in the same areas, most commonly in areas where the consolidation was problematic at the time of treatment, and mainly in areas with several paint layers (i.e., a thicker structure of paint). This was visually observed during treatment. Some areas needed several applications or point consolidation to consolidate the flaking paint. It is reasonable to assume that the painting technique, the thickness of the paint layer as well as the varying distribution of the sturgeon glue added to the paint, cause the thicker paint layer to reflake.

Consolidation treatment using sturgeon glue on thin paint layers in the early 1990s was still in good condition, while consolidated thicker paint layers, when revisited after a year or two, generally had flaking paint after treatment. In our experience, sturgeon glue seems to be an efficient choice when the binder in the total paint layer is degraded, and a ‘new’ binding media is needed. It might be said that sturgeon glue is more a supplementary binder for a weak structure than a glue that binds flaking distemper paint. An exception is when the paint structure consists of two relatively thin layers, and the uppermost layer is flaking.

Another critical issue to discuss is the experience and skill of the conservator. The method might look like a routine procedure, but it requires knowledge about the distemper paint technique, an interest in the challenges of consolidation and the ability to remain focused and study the paint structure and the effect of the consolidation whilst working. Moreover, we need to broaden our knowledge of how to adjust consolidation treatment to the various types of paint structure and damages.

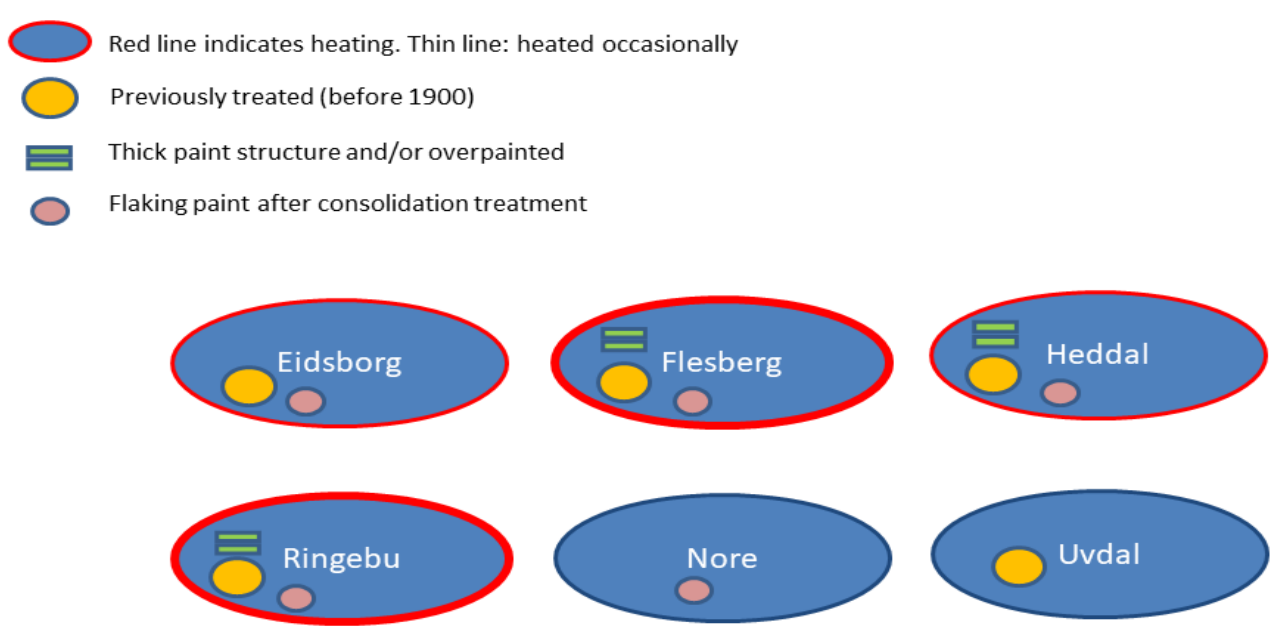

Figure 7: Compilation of the parameters from the six selected stave churches. Figure: NIKU 2022.

Comparing the parameters

A) The painting technique, including the application, number of layers, thickness, binding medium and pigments as well as additives to the paint.

The painting technique, use of pigments and number of layers are mostly the same in the Uvdal, Nore and Flesberg stave churches, as the seventeenth-century paintings are attributed to the same anonymous painter. Seventeenth- and eighteenth-century paint layers are, in general as well as in these three churches, thin, with one or two motif layers on (usually) a white ground layer (Olstad 2016). An additional eighteenth-century painting in Nore, painted on parts of the building added in the eighteenth century, has thicker areas that were probably painted with a high concentration of glue-based binding media. In these areas, the paint is flaking off from the ground layer following the consolidation.

Figure 8: Flaking paint on the north wall in the chancel of Heddal stave church. Photo: Mille Stein, NIKU, 2013.

Eidsborg stave church has two different distemper decorative paintings: a painting on the north wall dated 1604 and a painting on the south wall dated 1640. The painting technique on the north wall is thin and roughly applied with a wide brush, while the painting technique on the south wall is thicker and with more layers. The condition report before treatment in 2007 also specified that there was some loose paint on the north wall and an extensive amount of loose paint on the south wall (Solberg et al. 2007). This may indicate that several thicker layers are more susceptible to flaking and reflaking.

Both the Heddal and Ringebu stave churches have distemper decorative paintings with several paint layers and thick paint structures, often due to overpainting. Layers up to 1.5 mm thick were observed. Overpainting with distemper paint increases the thickness of the paint layer and complicates the penetration of the sturgeon glue. The Heddal and Ringebu stave churches both had reflaking paint 2–3 years after consolidation treatment.

The pigments used in the distemper decorative paintings are mostly the same and were all available in the seventeenth century. Prior analyses did not reveal pigments other that what would have been readily available at the time (Olstad 2016; Kjølsen Jernæs and Ørnhøi, 2021). Our experience suggest that some pigments need more consolidation material during treatment. This might be related to the chemical properties of the pigment but also to the technical build-up of the paint layers, for instance, a thin paint layer over a thick one or a clay earth pigment under a thinner paint layer. It was observed when applying the sturgeon glue method that red pigments in general seemed to need more attention and that thicker paint strokes could be problematic to consolidate.

Based on painting with variations of distemper paint, we found that the quality of the paint and how it is applied influences how it adheres to the wall or underlying paint layer and thus likely impacts the future condition of the distemper paintings. The choice of pigment, binding media, the ratio between the pigment and binding media and the painters' 'hand' are all important to the final result.

B) Past conservation treatments - including overpainting.

The former consolidation treatments did not, in our experience, seem to complicate the last treatment with sturgeon glue, but the overpaint did, both where it remained and in the areas where the overpaint had been removed. Three of the six selected paintings, Eidsborg, Heddal and Uvdal, were partially consolidated by other conservators before they were treated by NIKU. Documentation of these former treatments is scarce, but some treatments such as overpainting and retouching are readily visible by visual examination.

Additives such as egg, casein and oil have been found in several distemper decorative paintings (Olstad 2016). These additives are assumed to be (and in some cases identified as) part of the original painting technique. However, there were no indications in treatment reports or in interviews with project leaders that these additives have contributed to the difficulties in treatment.

C) The consolidation method applied, possible changes in the consolidation method or the personal 'touch' of the conservator.

There was an agreement among the conservators we interviewed that one cause for the partial failure of the sturgeon glue method might be variations in the personal engagement in the work. It is sometimes difficult to maintain concentration when working on large areas. During the thirty years in which the method has been in use, there seems to have been a shift in focus. In the 1990s, considerable attention was given to adapting the method to each area being consolidated, always considering the best way to consolidate and get the glue to penetrate whilst using as little of it as possible. As time passed, there was less focus on examining the paint decoration in detail and more on using the same application method for the whole paint decoration—and an even greater emphasis on the glue concentration in the consolidation material.

Over the years, sturgeon glue has been purchased from various suppliers, but we have not found that to be the cause of any of the consolidation problems. The ratio of sturgeon glue solution has always been adjusted to each distemper painting based on tests and experience and differs from treatment to treatment. The treatment reports from the 1990s often describe small modifications, for example, applying the consolidation material without Japanese tissue or performing multiple applications in certain areas. It seems the methods have been customised to the area being treated.

D) Temperature and relative humidity, both during the conservation campaign as well as the climate in the church during the year; heated/unheated or intermittent heated.

Of the nineteen stave churches with distemper paintings, thirteen are unheated. Of the selected six stave churches, Uvdal and Nore are unheated, Flesberg and Ringebu are heated and Heddal and Eidsborg are heated occasionally. Relative humidity and temperature have been monitored in some of the stave churches as part of other projects (Olstad et al., 2020) and it seems the impact of the climate on distemper decorative paintings is particularly evident in heated churches situated in a dry inland climate. The relative humidity in these heated churches, as in Ringebu, fluctuates and shows extraordinarily low values during heating episodes in winter (Olstad et.al, 2020). The fluctuating humidity causes individual layers in the structure to expand and contract at different rates, in turn leading to cracking and flaking in the decorative layer (Bratasz, 2013).

Unfortunately, the temperature during consolidation campaigns was not recorded by the teams working in the churches, with one exception. When the work in Heddal stave church started in September 2008, the temperature on the surface of the painted wall was 11°C, the temperature of the glue solution varied between 40 and 50°C and the conservators observed that the glue did not penetrate the paint layers. The church was additionally heated, and the next day the surface temperature was between 14 and 18°C, allowing the work to proceed. The temperature of the glue solution was raised to between 50 and 60°C.[7] The work demanded a certain temperature on the wall, and penetration was made easier with a warm solution. In Norway, it is therefore recommended that consolidation with sturgeon glue is done during the warmer part of the year and in heated churches.

We have generally found that the temperature on the wall as well as the temperature of the sturgeon glue solution are important for the penetration of the glue into the paint layer. It is interesting to consider our

findings in light of the paper by Soppa et al. (2014) on penetration depending on the temperature of the sturgeon glue solution. The paper reported that a 40°C sturgeon glue solution penetrated further into a chalk ground than a 28°C solution (Soppa et al., 2014: 4-7).

Based on this paper and our practical experience, documented in Heddal stave church but seen in more cases, it appears that both the temperature of the sturgeon glue solution and the temperature of the painted wall itself affect the penetration of the consolidation material. However, we still do not know the factors that influence the binding of the glue within the structure. We wondered if the different pigments might contribute to the placement of the sturgeon glue in the paint structure, as some pigments need more binding media and tend to absorb more of the consolidation material than other pigments (Kjølsen Jernæs and Ørnhøi, 2021: 173).

E) Frequency of use, which is important both for the climate and the wear and tear of the paintings.

Consequences of use are closely associated with heating and the number of visitors. The Eidsborg, Nore, Uvdal and Heddal stave churches are considered to be museum churches, are rarely or never heated but have a high number of visitors, especially during the summer months. Ringebu and Flesberg are regular parish churches, heated and in regular use throughout the year, although they are also visited by tourists during the summer months. There is no significant difference in the wear caused by visitors in the churches.

Results from the analyses

Analyses of distemper binding media samples from the six selected stave churches revealed the use of animal-based collagen (unknown animal), the presence of proteins (CATS 2015; Krekel and Schultz 2019: 5–6) and additives in the form of drying oil (CATS 2015), casein (Solberg and Olstad, 1998) and ovalbumin, which is a protein found in eggs (Krekel and Schultz, 2017: 2; Krekel and Schultz, 2019: 2).

Regarding the presence and penetration of sturgeon glue in treated samples, ELISA and IFM analyses showed differences in the penetration in the distemper paint, both in thin/thick layers and in single/multiple layers. The IFM analyses indicated that different pigments need different amounts of binding media, and this leads to variation in the amount of consolidation material that is absorbed (Kjølsen Jernæs and Ørnhøi, 2021: 172-173). According to the ELISA/IFM analysis, it would appear that the consolidation material remains in the upper layer of the paint structure and does not reach the inner part of the paint or the gap between the paint and the wood (Kjølsen Jernæs and Ørnhøi, 2021: 173).

In general, the scientific analyses did not yield significant results. Even the results of the ELISA/IFM analyses might be subject to dispute due to, for example, saturation. When pigments that need larger amounts of binding media are located in the uppermost layers of a paint structure in need of consolidation, they may potentially absorb all the consolidation material, leaving none for the rest of the paint structure. Therefore, it seems the painting technique plays a larger role than expected; the ratio of binder to pigment, the type of pigment, the thickness of the single decorative stroke and the total thickness of the paint layer seem to have a substantial impact on the consolidation treatment. These are research questions that still need to be answered. However, the theory that various pigments, requiring different amounts of binder, would need different amounts of consolidation medium, even when the condition of the paint is the same, was strengthened by the IFM analysis. The challenges related to consolidating thick and/or multiple layers are probably due to the pigments within the paint structure and the assumed variation of temperature in the paint layers.

The preliminary answers from the analyses are consistent with our practical experience. When we have tried to insert the consolidation material along the edges of losses, the glue has not always formed a bond between paint and wood. Furthermore, in distemper decorative paintings, consolidation with sturgeon glue is often unsuccessful even after several applications.

Possible future research

There is a need for continued research to understand the challenges of using sturgeon glue in the consolidation of distemper paintings. Such research should not only focus on the analytical aspects but also on hand skills and conscious experience. In a small way, the questions raised reflect the difficulty of being a conservator, with one leg in the research world and the other in the practical skill world. These worlds must be combined positively. The discussions were based

on the conservators' experiences and assumptions. These experiences and practical-based views are crucial but must be supported and confirmed by organised testing and further analyses.

NIKU is continuing the research on sturgeon glue as well as seeking to find a suitable additional consolidation agent for distemper paint when sturgeon glue might not be the preferred choice. The focus now is on methylcellulose as an alternative to sturgeon glue, which might be particularly useful for thick layers of distemper paint.

Conclusion

Sturgeon glue is still a highly favourable consolidating agent for distemper paint in Norway. It has qualities that are important when consolidating matte paint. The questions regarding its suitability, which motivated NIKU's research and this paper, are by no means a reason to disregard it completely.

The results from our hands-on experience and analyses suggest that sturgeon glue does not penetrate beyond the top layers of the paint structure, which results in paint flaking in distemper decorative paintings with several paint layers and a thicker structure. We are reasonably certain that the thickness of the paint layer is crucial for the success of the consolidation treatment. The room temperature, temperature of the glue and application method may also impact the result. Our study did not find evidence indicating that previous treatments are an obstacle to the successful use of sturgeon glue. However, the conservator's role as a variable should not be underestimated when evaluating the consolidation results.

The methods and use of sturgeon glue should be adjusted for different paintings, and its use should likely be restricted to thin layers of distemper paint or to distemper paint that is disintegrated and requires an additional binder. NIKU will continue using sturgeon glue as long as there is no alternative consolidation agent that works as well or better than sturgeon glue for various types of surfaces on distemper decorative paintings in stave churches, but will limit its use to structures for which, based on our knowledge and experience, we strongly believe it will work. NIKU will research sturgeon glue-based consolidation, seeking to learn more about where in the structure the consolidation material remains and how the consolidation material might be targeted to where it is needed in the structure.

Acknowledgements

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Endnotes

1. NIKU is a non-governmental organisation and an independent institute within the wider field of cultural heritage in Norway and beyond. NIKU offers heritage services to private and public customers, conducts research and advises on art, interiors and buildings. NIKUs Conservation Department works on-site and on objects brought to the workshop in Oslo. For more information, visit: https://www.niku.no/en/

2. Stave construction is a method of building with posts—staves—as the load-bearing elements. In principle, a stave building is a frame construction consisting of horizontal and vertical elements resting on stone foundations on the ground (Anker 2016).

3. The research assignment given to NIKU by the Directorate for Cultural Heritage is a part of the national assignments directed by the Norwegian Ministry of Climate and Environment.

4. The consolidated and examined paintings are in the following churches: Eidsborg, Flesberg and Nore (some flaking paint), Heddal (flaking paint), Hopperstad, Kaupanger, Kvernes, Ringebu, Grip, Torpo, Gol and Urnes (not examined) and Uvdal (in very good condition). Of these churches, the following distemper decorative paintings have been documented as consolidated: Eidsborg, Heddal, Kvernes (choir), Grip (only small test areas), Torpo (three times) and Gol.

5. Some flaking occurred in areas where the painting technique made it difficult to consolidate the paint.

6. An assessment of the preferred method of consolidation was conducted, along with interviews with conservators who had previously worked with this method, to identify any changes in the consolidation method.

7. The relative humidity in the church varied between 55% and 64% during the work period.

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