MOK

MEDDELELSER OM KONSERVERING

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MOK

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Kære læser,

I de kommende år vil redaktionen sætte fokus på at øge synligheden af Nordisk Konservatorforbunds fælles tidsskrift 'Meddelelser om Konservering' (MoK).

Bladet er siden 1960 blevet udgivet som et fælles Nordisk tidskrift. Vores mål er at dele viden om videnskabelig forskning og fremskridt inden for bevaringspraksis, metoder og teknikker samt at styrke samarbejdet mellem de Nordiske lande.

Redaktionen er i den forbindelse glade for at kunne annoncere at MoK de kommende år vil blive frit tilgængelig online takket være et generøst bidrag fra *Märta, Gunnar og Arvid Bothéns Stiftelse*. Vi håber at dette kan være med til at forbedre samarbejde og vidensdeling mellem konservatorer i de Nordiske lande.

MoK indeholder i år seks fagfællebedømte artikler. Artiklerne spænder vidt fra metoder til vurdering af tidligere udførte konserveringer, erstatningsprodukter for maling i Norge under verdenskrigene, en oversigt over effektive rutiner til at bevare historiske interiør, metoder til at behandle overfladen på 3D printede polymere over til delaminering af den franske kunstner Pierre Soulages malerier.

Redaktionen vil gerne sige tak til forfatterne for deres fine bidrag samt det store arbejde der udføres af fagfællebedømmerene. Vi håber at I medlemmer også fremadrettet vil støtte op om vores tidsskrift og blive ved med at indsende jeres bidrag.

Vi har fået en del nye medlemmer i redaktionen. Jeg vil gerne sige tak til vores redaktør Thea Winther fra Sverige, Marie Kleivane fra Norge og María Karen Sigurdardóttir fra Island for det store arbejde de har lagt i dette års blad. Også et stort tak til vores redaktør Jaana Kataja fra Findland som har stået for annonceringen i år og vores nye kassere Lea Høyrup Nedergaard.

Hvis I har spørgsmål, er I altid mere end velkomne til at kontakte redaktionen på editor-in-chief.mok@nordiskkonservatorforbund.org.

God læselyst!

Signe Hjerrild Smedemark
Chefredaktør MoK 2021

Dear reader,

The editorial team will, within the next few years, focus on increasing the visibility of the Nordic Association of Conservators common journal 'Meddelelser om Konservering' (MoK).

The journal has been published as a collaboration between the Nordic countries since 1960. Our goal is to share knowledge about scientific research and progress in conservation practice, methods and techniques as well as to strengthen collaboration between the Nordic countries.

The editors are therefore pleased to announce that MoK will be available online for the next few years thanks to a generous grant from the *Märta, Gunnar and Arvid Bothéns Foundation*. We hope that this will help improve the collaboration and knowledge sharing between conservators in the Nordic countries.

This year, MoK contains six peer-reviewed articles. The articles range from methods for assessing conservation treatments, substitutes for paints used in Norway during the World Wars, an overview of effective routines for preserving historic interiors, methods for treating the surface of 3D printed polymers, and finally degradation of Pierre Soulage's paintings.

The editors would like to thank the authors for their contributions as well as the remarkable work done by the peer-reviewers. We hope that you will continue to support MoK and consider submitting your contributions in the future.

Finally, I would also like to introduce some new members in the editorial team. I would like to thank our editor Thea Winther from Sweden, Marie Kleivane from Norway, and María Karen Sigurdardóttir from Iceland for the enormous work they have put into this year's MoK. Also big thanks to our editor Jaana Kataja from Finland who has been responsible for advertisements and our new cashier Lea Høyrup Nedergaard.

You are always welcome to contact the editors if you have any questions at editor-in-chief.mok@nordiskkonservatorforbund.org.

Signe Hjerrild Smedemark
Editor-in-chief MoK 2021

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GOD PRAXIS FÖR UTVÄRDERING AV TIDIGARE KONSERVERINGAR

Sammanfattning

Konservering påverkar kulturarvet. Att utvärdera tidigare konserveringar och använda utvärderingsresultaten för välgrundade beslut är ett sätt att hantera risken för oönskade effekter över tid. I den här artikeln presenteras en litteraturstudie där vedertagna begrepp inom området utvärdering relateras till utvärdering av konserveringsmaterial och konserveringsmetoder. De viktigaste principerna handlar om att utvärderingen ska vara framåtsyftande och att den ska underbyggas av en genomarbetad värderingsmodell med tydliga bedömningskriterier. Även metoder för att utvärdera på ett icke-invasivt sätt diskuteras.

Abstract

Conservation treatments change the cultural heritage. One way of managing the risk of unwanted effects of conservation is to evaluate previous work and use the results for new, well-informed decisions. In this paper, basic concepts in evaluation theory are related to conservation evaluation. The main principles of evaluation theory imply that an evaluation should be useful for improving a practice and that it should be supported by a thorough valuation model with clear judgement criteria. Methods for non-invasive evaluation of previous treatments are briefly discussed.

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Nyckelord:
Utvärdering; kvalitetssäkring; uppföljning; konserveringsutvärdering.

Keywords:
Evaluation; quality assurance; review; assessment.

Introduktion

Det finns en risk att en konserveringsåtgärd inte fungerar som den är tänkt över tid. Konservatorer försöker förebygga den risken, till exempel genom att använda material som har genomgått laboratorieanalyser. Ett annat sätt är att utvärdera naturligt åldrade konserveringar. I artikeln “Data in conservation: the missing link in the process” från 1999 har Suenson-Taylor, Sully och Orton gett goda råd för epidemiologiska utvärderingar av tidigare konserveringar. Utöver det har diskussioner om utvärderingspraxis av naturligt åldrade åtgärder varit ovanliga i konserveringslitteraturen.

Den här artikeln bygger på delar av min masteruppsats (se Anderson 2019). Uppsatsens syfte var att teoretiskt formulera en metodik för icke-invasiva utvärderingar av tidigare utförda aktiva konserveringsåtgärder. I detta utdrag besvaras frågan om hur ämnesområdet verksamhetsutvärdering kan appliceras på konservering och vilka metoder som kan vara aktuella för icke-invasiva utvärderingar av aktiva konserveringsåtgärder. Dessutom diskuteras vilka kvalitetssäkrande principer som kan utgöra god praxis för konserveringsutvärdering. Förhoppningsvis kan artikeln inspirera konservatorer, uppdragsgivare och myndigheter så att fler utvärderingar kan genomföras i framtiden.

MoK

Metod, källor och avgränsningar

Utvärdering är ett komplext område. Det kan hjälpa att ta inspiration från såväl naturvetenskapliga som humanistiska angreppssätt. I denna litteraturstudie relateras utvärdering av tidigare konserveringar till grundläggande koncept inom svensk verksamhetsutvärdering.

Tre källor har använts för att förstå verksamhetsutvärdering som ämnesområde: Gröjer (2004), Forss (2007) samt Sandberg och Faugert (2016). Vedertagna koncept inom konservering har huvudsakligen inhämtats från yrkesetiska och brett överenskomna dokument: ICOMs etiska regler (2017), E.C.C.O:s riktlinjer (2003) och SIS-standarden ”Kulturvårdsprocess - Beslut, planering och implementering” (2017). Området kvalitetssäkring inom konservering har belysts med hjälp av Fellers (1994) skrift om accelererad åldring, Taylors (2013) och Taylor och Stevensons (1999) resonemang om subjektivitet och fallgropar vid okulär undersökning av objekt, samt Suenson-Taylor, Sully och Ortons (1999) artikel om epidemiologiska utvärderingar av tidigare konserveringar. Ashley-Smiths (2013) rapport om *Damage functions* har använts för att förstå de kvantifierbara faktorernas roll för konserveringsutvärdering. Svahn (2006) och Svahn Garreaus (2007) rapporter samt Myrins (2006) avhandling har bidragit stort till förståelsen av hur icke-invasiva undersökningsmetoder har använts vid utvärderingar av aktiva konserveringsåtgärder i Sverige.

Följande avgränsningar har gjorts:

- Utvärdering av konserveringsmetoder och -material genom accelererad åldring, simuleringar eller genom studier av substitutmaterial tas inte upp.
- Resonemanget gäller huvudsakligen inte invasiva utvärderingar.
- Resonemanget gäller huvudsakligen inte förebyggande åtgärder.

Vad är utvärdering?

”Med hjälp av utvärdering betygsätts historien”, så skriver Gröjer (2004: 5) och menar att utvärdering handlar om att systematiskt använda sig av sina erfarenheter. Forss (2007: 10) poängterar att människor alltid har utvärderat sina aktiviteter i ett ständigt sökande efter förbättrade lösningar på problem.

Sandberg och Faugert (2016: 11) definierar utvärdering som ”en systematisk undersökning av en aktivitets värde och betydelse”. Med *systematisk* avses att arbetet är strukturerat och metoderna vetenskapliga och vedertagna (2016: 12). Forss (2007: 10) ger en liknande engelskspråkig definition, där ordet objekt (object) används istället för aktivitet. Objekt kan stå för i princip vad som helst: en företeelse, en verksamhet, en handling, ett beslut, en policy eller ett fysiskt objekt.

Översatt till konservering skulle den utvärderade aktiviteten eller utvärderingsobjektet vara effekten av en konserveringsmetod eller ett konserveringsmaterial. Det är inte det kulturhistoriska objektet som värderas, utan arbetsprocessen som lett till objektets aktuella tillstånd. Inom konservering vore det därför lämpligare att använda ordet *utvärderingsämne* istället för det vedertagna *utvärderingsobjekt* för att inte skapa missförstånd om att det är det kulturhistoriska objektet som ska utvärderas.

Forss påpekar att utvärdering är en process och inte den rapport som produceras i samband med processen (2007: 14). Utvärderingens resultat och effekter ska dock redovisas i ett slutgiltigt värderingsomdöme. Ett sätt att skilja begreppen resultat och effekter åt kan enligt Forss (2007: 49-50) vara tidsdimensionen, där resultat åstadkoms i direkt anslutning till en insats, medan effekt uppkommer efter att en tid har passerat och relaterar till insatsens syfte. Sandberg och Faugert (2016: 65) skriver att en effekt inte alltid motsvarar den utvärderade aktivitetens mål, utan kan vara både önskade och oönskade samt förväntade och oväntade utfall. Applicerat på konservering skulle resultatet av konserveringen vara beskrivet i konserveringsrapporten, medan effekten skulle vara det som kan observeras när en tid har passerat och där flertal förändringsorsaker (till exempel klimatfaktorer eller objektets hanteringshistorik) har samverkat.

Begreppen validitet och reliabilitet är centrala inom utvärdering. Validitet handlar om att mäta det som verkligen är relevant för utvärderingen och om resultaten kan generaliseras (Sandberg & Faugert 2016: 151). Sandberg och Faugert (2016: 152) påpekar dock att låg generaliserbarhet inte nödvändigtvis är ett tecken på en dålig utvärdering i de fall utvärderingens syfte är att studera en specifik åtgärd i relation till åtgärdens mål. Reliabilitet handlar om noggrannhet och systematik i en utvärdering. Om en undersökning genomförs på nytt bör resultatet kunna bli likvärdigt

(Sandberg & Faugert 2016: 153). Reliabilitet handlar också om att utvärderarens roll i förhållande till utvärderingens syfte och motiv, ska vara tydlig (Sandberg & Faugert 2016: 153).

Enligt Gröjer (2004: 9) skiljer sig en utvärdering från en uppföljning. Uppföljning är en regelbunden insamling och sammanställning av ofta kvantitativa data som till skillnad från utvärderingar varken tolkas eller förklaras. Enligt Sandberg och Faugert (2016: 12) redovisar en uppföljning ett resultat på ett så värderingsfritt sätt som möjligt, medan det vid utvärdering görs en systematisk värdering. Skillnaden mellan utvärdering och forskning, menar de, är att forskning ofta syftar till att bevisa eller motbevisa en teori, medan utvärdering oftast syftar till förbättring av en aktivitet (2016: 13).

Syften och motiv vid utvärderingar

Också Forss (2007: 15-18) menar att nyttoaspekten är det som skiljer en utvärdering från andra systematiska undersökningar, exempelvis att utvärderingen ska användas som ett beslutsunderlag, att något ska kontrolleras eller för att bygga på kunskap. Konserveringsexempel som kan svara mot dessa syften ges i tabell 1.

Gröjer (2004: 7) skriver att olika motiv och syften är vanliga inom olika discipliner. Inom förvaltning och politik sker utvärderingar främst för att kunna ta nya välgrundade beslut (2007: 4). Inom högskoleväsendet utvärderas ofta enskilda program eller kurser och det görs skillnad mellan *formativa* och *summativa* utvärderingar. En formativ utvärdering genomförs parallellt med utbildningsprocessen i syfte att justera utbildningen samtidigt som den pågår. I en summativ utvärdering utvärderas resultatet av kursen eller programmet (2007: 8,184). Enligt Gröjer (2004: 184) utförs summativa utvärderingar (bedömning av resultat och effekt) liksom resultatinriktade utvärderingar (jämförelse mellan utfall och mål) inom högskoleväsendet oftast av granskande, kontrollerande och externa utvärderare, exempelvis finansiärer.

Inom konserveringsutvärdering skulle kortsiktiga syften kunna handla om att få svar på konkreta problem, exempelvis att kontrollera om konserveringen motsvarar beställningens krav eller att avgöra om objektet behöver omkonservering. Långsiktiga syften kan vara kunskapsuppbyggnad kring metodernas och materialens långtidseffekter, metodjämförelser, förståelse av nedbrytningsprocesser eller av hur kulturvårdsresurser används.

God praxis inom dagens konservering innefattar en sorts formativ utvärdering där konservatorn utvärderar den egna åtgärden. I standarden ”Kulturvårdsprocess

Utvärderingens nyttoaspekter enligt Forss	Motsvarande exempel inom konservering
Underlag för beslut. Utvärderingen syftar till att ta reda på hur det förhåller sig, och resultaten leder vidare till beslut om vad som ska hända.	Ska konservatorer fortsatt använda metoden eller materialet inom konservering? Fungerar metoden för en kommande konservering eller bör andra metoder undersökas?
Kontroll. Vilken effekt eller nytta har en åtgärd? Utvärderingen behöver inte leda till beslut utan kan också visa att det som kontrollerats fungerar bra.	Fyller konserveringen den tänkta funktionen? Är konserveringen utförd enligt beställningen? Behöver objektet ytterligare konservering?
Lärande. Utvärderingen tar fram information och hjälper till att skapa kunskap genom systematisk och vetenskaplig bearbetning av data. Lärande kan ske genom att ta del av utvärderingens resultat, eller genom processanvändning.	Uppföljning av egna arbeten. Ökad förståelse av förändringsprocesser i material. Ökad förståelse för konserveringens beslutsprocesser.

Tabell 1. Beskrivning av utvärderingens nyttoaspekter enligt Forss (2007: 15-16) och exempel på frågor som dessa kan motsvaras av inom konservering.

– Beslut, planering och implementering” står att kvalitetssäkring innebär en löpande avstämning av åtgärdens ändamålsenlighet under den pågående konserveringen (SIS 2017: artikel 10.3). Konservatorn undersöker metodens och materialens lämplighet i relation till objektet, testar på ett dolt ställe, justerar metoden, avbryter om tecken på olämplighet uppstår, och summerar resultatet av åtgärden i en resonerande konserveringsrapport. I Sverige genomför länsstyrelserna kontroll av dokumentation och i vissa fall platsbesök efter genomförd konservering (gäller främst svenska kyrkor). Detta kan ses som en motsvarighet till en kontrollerande eller resultatinriktad utvärdering som beskrivs ovan. Det förefaller dock finnas få andra tillfällen där utvärderingar sker i efterhand, vare sig det rör sig om ett lärande, kontrollerande eller beslutsgrundande motiv.

Eftersom utvärderingens motiv påverkar utvärderingens reliabilitet bör det redovisas öppet och tydligt. Motivet avgör om det krävs en extern oberoende utvärderare eller om utvärderingen kan göras av samma personer som utfört konserveringen. Att enskilda yrkesutövare följer upp och utvärderar sina egna arbeten kan understödjas av artikel 12 i E.C.C.O:s yrkesetiska riktlinjer (2003), där det framhålls att konservatorer ständigt ska sträva efter att förbättra sina metoder.

I svaren på en enkätundersökning om utvärdering bland konservatorer i Sverige framkom att ett vanligt tillfälle för att utvärdera en tidigare konservering är inför kommande omkonserveringar (Anderson 2019: 28). Respondenterna uppgav ytterligare motiv eller utvärderingstillfällen:

- Inför konserveringsåtgärder kan provytor konserveras och därefter utvärderas.
- Vid rutinmässig tillståndsbedömning, för att bättre förstå objektets skadehistorik.
- När en skada hos ett tidigare konserverat objekt har upptäckts.
- För att undersöka hållbarheten över tid hos konserveringsmaterial eller metoder.
- En person uppger att utvärdering av någon annans konserveringsåtgärd har gjorts i samband med ett rättsfall.

Utvärderarens ansvar

Forss (2007: 45) påpekar att den som utvärderar alltid kommer att hitta något att kritisera och menar att utvärderarens resultat ska vägas mot de konsekvenser som en förändring i det utvärderade fältets praktik skulle innebära. Vid konserveringsutvärdering bör utvärderaren tänka på att resultaten kan leda till förädringar i konserveringspraktiken och därmed påverka kulturarvet. Ett fiktivt exempel kan vara att en utvärderare kommer fram till att ett konserveringsmaterial brister i något hänseende, och avråder från att använda materialet trots att inget motsvarande och bättre finns på marknaden. Risken är att de skador på kulturarvsobjekt som materialet används för inte konserveras alls. Ett förslag på ett materialforskningsprojekt skulle i detta fall möjligen vara ett mera användbart och framåtsyftande utvärderingsresultat än ett avrådande.

Utvärdering inom statsförvaltning beskrivs av Gröjer (2004: 5) som ett maktmedel, eftersom resultaten påverkar nya beslut. Gröjer fortsätter: ”[d]et är inte ovanligt att ut-värdering uppfattas negativt genom att den egna verksamheten blir värderad och i värsta fall ut-klassad” (2004: 5). Då konservering är ett begränsat yrkesfält kan utvärdering av kollegors, föregångarnas eller konkurrenternas arbeten upplevas som otrevligt. Otrevliga situationer skulle kunna undvikas genom att konserveringsfältet enas om god praxis för kvalitetssäkring genom utvärdering, till exempel att den enskilda utvärderaren tydligt ska redovisa utvärderingens motiv, syfte och bedömningskriterier, samt att en utvärdering planeras in redan vid konserveringen.

Att värdera

Enligt Forss (2007: 7-8) är utvärderingsprocessens grundläggande element datainsamling, analys av data samt den värderande processen. Hur dessa steg kan förstås inom konservering föreslås i tabell 2.

Värderingsprocessen påverkas av flera faktorer: undersökningens design, undersökningsinstrumenten, hur den förklarande modellen ser ut, arbetsmomentens ordning. Hur oväntade situationer hanteras kan också påverka värderingsprocessen. Oväntade situationer kan exempelvis vara att bieffekter eller synergieffekter upptäcks, eller att data visar sig vara svårfunnen, svårtolkad eller tvetydig.

Forss (2007: 13) argumenterar för att värde kan mätas med kvalitativa metoder om utvärderingen är noggrann, systematiskt genomförd, dataredovisningen öppen och det finns en tydlig beskrivning av hur ”värde” har bestämts. Sandberg och Faugert (2016:

13) påpekar att de värderingskriterier som väljs ska vara styrande för datainsamlingen. Ett problem vid verksamhetsutvärdering är att kriterier ofta utgörs av politiska eller administrativa mål. Sådana abstrakta kriterier, skriver de, är i praktiken oanvändbara.

Inom konservering finns övergripande kvalitetsprinciper beskrivna i dokument som ICOMs etiska regler (2017), E.C.C.O:s riktlinjer (2003) och den europeiska standarden ”Kulturvårdsprocess - Beslut, planering och implementering” (SIS 2017). Sådana principer

Utvärderingens element enligt Forss	Förslag på motsvarighet inom konservering
Förklarande modell med beskrivning av hur värde har avgjorts.	Enligt vilka kriterier ska bedömningen göras? Vad var konserveringens syfte? Vilket är det önskade resultatet eller den önskade effekten av konserveringen? Vad räknas som icke-önskvärd förändring (skada) i det aktuella fallet? Vilka är de förväntade tecknen på att metoden/materialet inte uppfyllt det önskade resultatet/effekten? Formulering av definitioner och skalor för datainsamlingen.
Ordning på arbetsmomenten.	Vilket ska göras först: analys av konserveringsdokumentation eller undersökning av objekt? Krävs en pilotstudie?
Metod för datainsamling.	Finns konserveringsdokumentationen? Finns det annan dokumentation som kan bygga på informationen om objektets tillstånd? Ska analytiska tekniker eller endast okulär undersökning göras? Ska en eller flera utvärderare delta? Användning av formulär, mallar, klassifikationsmodeller.
Undersökningsinstrument.	Utvärderaren (okulär undersökning), verktyg som lampor och lupp, analysfotoutrustning, standardiserad terminologi, standardiserade skalor, bedömningskriterier etc.
Metod för bearbetning och analys av data.	Diagnostisering, bedömning, värdering. Statistiska metoder.
Hur hanteras det oväntade? Till exempel att datainsamlingen inte går som man tänkt, uppgifter som behövs finns inte.	Hur hanteras avsaknad av konserveringsdokumentation? Vad händer om det inte går att komma åt att undersöka objektets alla delar, exempelvis en väggförankrad baksida?

Tabell 2. Utvärderingens element som ska upprättas innan en utvärdering kan påbörjas, så som de beskrivs av Forss (2007: 13) och förslag på motsvarande steg eller frågor inom konservering.

är vägledande i konserveringens praktik, men utan förklarande värderingsmodeller är de alltför abstrakta för att användas som utvärderingskriterier. I värsta fall skulle utvärdering utifrån koncept som kompabilitet eller reversibilitet kunna leda till moralistiskt dömande. Ett utlåtande om ”minsta möjliga åtgärd” skulle lätt kunna bli godtyckligt i vad som anses vara ”för mycket” eller ”tillräckligt lite”. Dock bör övergripande kvalitetsprinciper användas till att guida värderingsmodellerna.

Sambandet mellan orsak och verkan

Många faktorer bidrar till konserveringens effekt utöver konserveringsmetoden och konserveringsmaterialet, till exempel objektets omgivning, förflyttning mellan olika lokaler, mänsklig och mikrobiell aktivitet, tidigare åtgärder och mycket mera. Hur ska en utvärderare avgöra vilka delar i den observerade effekten som ska tillskrivas den utvärderade konserveringsåtgärden?

Inom verksamhetsutvärdering är orsakssambandet ett centralt koncept. Sandberg och Faugert (2016: 21) varnar för att ett enkelt konstaterande av ett resultat kan leda till felaktiga rekommendationer. Resultatet kan bero på många omvärldsfaktorer, därför ska inte ett observerat tillstånd likställas med effekterna av en aktivitet. Istället bör de mekanismer som gör att effekterna uppstår identifieras.

Feller (1994: 22) påpekar att det vid utvärdering av konserveringsmaterial finns risk vilseledande observationer. Kemiska förändringsprocesser är sällan linjära. Det kan finnas en induktionsperiod, och processerna kan avta eller accelerera över tid. Feller (1994: 32-33) ger ett fiktivt exempel på en utvärdering av material A och B. Vid observationstillfället har A förändras mindre än B. Observatörens slutsats är att A är ett stabilare material. Vad observatören inte vet är att A vid ett senare skede kommer att förändras drastiskt till det mycket sämre, medan förändringen hos material B kommer att avta. Observatören har alltså dragit en felaktig slutsats på grund av att utvärderingen endast gjordes vid ett enskilt tillfälle och alldeles för tidigt. Exemplet handlar om accelererade åldringsstudier, men tanken kan appliceras på utvärdering av naturligt åldrat material. Enligt Feller (1994: 7-8) kan undersökningar av objekt i normala musei- och arkivförhållanden avslöja de konserveringsmaterial som är minst kemiskt stabila, medan de mest stabila materialen endast kan upptäckas genom laboratorietester där materialet har utsatts för extrema påfrestningar.

I en epidemiologisk konserveringsutvärderingstudie har Sully och Suenson-Taylor (1996: 178) anvisat att antalet objekt inte bör understiga 25 % av populationen för statistiskt säkerställda resultat vid undersökning av museisamlingar. I en studie om subjektivitet vid samlingsöversyner resonerar Taylor och Stevenson (1999: 23) att större mängd objekt i undersökningsurvalet i relation till populationen ökar reliabiliteten men kräver mera tid och resurser. Enligt dem kan en effektiv och representativ mängd objekt endast avgöras utifrån pilotstudier på samlingen i fråga.

1996 tillämpade Sully och Suenson-Taylor statistiska metoder för urvalsdragning och databearbetning vid utvärdering av glycerolbehandlat arkeologiskt läder, för att hitta påverkansfaktorer för konserveringens effekter. Utifrån studien sammanställde de råd för tillämpning av statistik vid epidemiologiska utvärderingar. Det är ovanligt att hitta så pass många likvärdiga objekt för att etablera statistisk säkerställda resultat för konserveringsåtgärders effekter. Statistiska metoder kan dock användas på andra sätt för att underbygga konserveringsutvärderingar, till exempel vid studier av bevaranderelaterad dokumentation eller insamling av konservatorers erfarenheter. Häggström et al. (2013) har samlat in statistik från konservatorer på museer inför en omfattande utvärdering. I en studie om datautvinning från museers samlingsförvaltningssystem skriver Golfomitsou et al. (2017: 8) att statistiska metoder kan tillämpas på bevaranderelaterad dokumentation för att ta reda på hur ofta objekt blir behandlade samt om vissa metoder leder till andra.

Det har gjorts vissa försök inom kulturvård att ta fram modeller för matematiska orsakssamband som relaterar kvantifierbara faktorer i objektets miljö till kvantifierbara effekter hos objektet (Ashley-Smith 2013: 7, 10). Sådana ekvationer kallas för *damage functions* (DF). Modelltypen har främst använts inom ekonomi och medicin. Kända kvantifierade värden skulle kunna användas i konserveringsutvärdering exempelvis för att på förhand estimera hur ett objekt borde ha förändrats och jämföra resultatet med den faktiska observationen. Vid avvikande skillnader skulle möjliga orsaker undersökas närmare. En annan applikation kunde vara att beräkna om en konservering med syfte att motverka miljörelaterad förändring (exempelvis mögelpåväxt, korrosion eller saltutfällning) har haft önskad effekt. En sådan studie skulle kräva att jämförelsevärden fastställts redan inför en åtgärd, eller går att återskapa med hjälp av dokumentation. Omvänt skulle epidemiologiska konserveringsutvärderingar

kunna bidra till att skapa statistiska modeller av hur material och metoder kan påverka objekt över tid.

Inom verksamhetsutvärdering har kvantitativa mål- och effektutvärderingar kritiserats för att alltför kraftigt förenkla en komplex verklighet (Sandberg & Faugert 2016: 21). Modeller för kvantitativa orsakssamband har ifrågasatts också inom konservering. Objektens unicitet och de många parametrarna försvårar framtagande av valida värden, något som exempelvis påpekats av Bylund Melin i studie av klimatrelaterade skador på träobjekt. Enligt Bylund Melin (2017: 73) är det troligtvis inte möjligt att kvantifiera de olika faktorernas påverkan på skadebilden, men tendenser går i viss mån att upptäcka.

Att en åtgärd haft en effekt är enkelt att konstatera, svårare är att mäta vad som ändå skulle ha skett vore det inte för åtgärden, skriver Sandberg och Faugert (2016: 22-24). För att lösa en komplex sambandsfråga kan flera olika utvärderingsmodeller och metoder behöva kombineras. Forss (2007: 28-29) skriver att det för utvärderingens validitet är nödvändigt att bygga upp tillräcklig kunskap om de förändringsprocesser som studeras. Även om fullständig säkerhet inte kan nås bör det åtminstone vara sannolikt att det som kontrolleras också är det som orsakar effekten.

Värderingsmodellen

Tydliga värderingsmodeller gör utvärderingar överskådliga, förståeliga och användbara för intressenterna. Modeller förklarar vad det är som bedöms och *vilka faktorer* som det värderande omdömet vilar på. Forss (2007: 100) skriver: ”[e]n modell kan ta många former; den kan vara matematisk och utryckas i form av en ekvation, det kan vara en serie med boxar som binds samman med pilar, eller en taxonomi som är listad i punktform. En modell kan också uttryckas rent kvalitativt i en löpande text”. Enligt Sandberg och Faugert (2016: 61-62) är utvärderingsmodeller mera innehållsrika än de vetenskapliga angreppssätten eftersom de omfattar praxis, idéer och idealbilder. Utvärderingsmodeller ska underlätta värderingen såväl metodologiskt som pedagogiskt och är förenklingar av en komplex verklighet.

Inom kulturvård används värderingsmodeller vanligen för att belysa kulturarvets olika värden och inte för att värdera en insats. Trots skillnaden kan värderingsmodeller för kulturarvets signifikans fungera som inspiration till konserveringsutvärdering. Ett exempel är ”Plattform för Kulturhistorisk värdering och urval”, där det framhålls att det inte finns en given modell som fungerar i alla situationer (Génetay & Lindberg 2014: 9). ”Vid en kulturhistorisk värdering ska en företeelses värden alltid preciseras, de egenskaper som representerar olika värden ska beskrivas och förklaras” skriver Génetay och Lindberg (2014: 15) och påpekar att det för trovärdighetens skull måste framgå vem som har värderat. I skriften ”Significance 2.0”, som handlar om att värdera betydelsen hos objekt på museer, arkiv och i bibliotek framhålls att bedömningen av signifikansen inte handlar om rankning utan om att förklara varför något är viktigt (Russell & Winkworth 2009: 14).

Dessa resonemang kan med lätthet appliceras på konserveringsutvärdering: utvärderingsämnet ska vara tydligt och värderingen ska underbyggas med förklaringar så att andra kan förstå bedömningens grunder. Värderingsmodellen ska förklara varför ett kvalitetskriterium för ett konserveringsmaterial har valts och beskriva vilka indikatorer som ska peka på att kriteriet har uppnåtts. Det kan till exempel vara otydligt för andra yrkesgrupper varför konservatorer anser att ett visst Tg är ett viktigt kriterium för ett lim.

Inom konservering skulle ett utvärderingsämne kunna vara att avgöra om konserveringen har uppfyllt sitt ändamål. Ett exempel är en utvärdering av metoder och material för konservering av sandsten där Myrin (2006) utvärderade ändamålsenligheten genom att studera effektivitet, hållbarhet och skyddande kapacitet. Metoden var okulär tillståndsbedömning som kompletterades med analytiska metoder (karstenrör och stötpulsmätningar) med mätningar före och en tid efter åtgärden. Ett annat exempel på utvärderingsämne är förekomsten av ett fenomen. I en utvärdering av alunbehandlat arkeologiskt trä undersökte Häggström et al. (2013) 1474 objekt för att hitta karaktäristiska nedbrytningstecken inför ett omkonserveringsprojekt. Värderingsmodellen innehöll en specialutformad klassifikationsmodell för okulär tillståndsbedömning.

Sandberg och Faugert (2016: 63) delar in utvärderingsmodeller i fyra olika typer: resultatinriktade, komparativa, teoribaserade och aktörsfokuserade. I tabell 3 finns dessa beskrivna tillsammans med exempel på frågeställningar inom konserveringsutvärdering.

Typ av utvärderingsmodell	Beskrivning	Exempel på motsvarighet inom konservering
Resultatinriktade modeller	Mäter resultat och kostnadseffektivitet. ”Klassiska” utvärderingsmodeller.	Frågeställningar om konserveringens effekter och ändamålsenlighet. Frågeställningar om orsakssamband.
Komparativa modeller	Denna typ av modeller hämtar sin kraft från jämförelser som antas kunna vara vägledande i en viss situation.	Jämförelser av hur olika metoder eller material har fungerat. Jämförelser av hur en metod fungerar på olika typer av objekt eller olika typer av skadebild. Jämförelse mellan estimerat utfall och faktiskt utfall.
Teoribaserade modeller	Denna typ av utvärderingsmodeller syftar till att ge svar på hur en åtgärd uppnår sina mål.	Kartläggning av de övergripande processerna som har lett till de effekter som kan observeras.
Aktörsfokuserade modeller	Dessa typer av utvärderingsmodeller studerar åtgärder utifrån olika aktörers perspektiv.	Frågeställningar där olika perspektiv på åtgärders lämplighet eller utfall finns.

Tabell 3. Fyra typer av utvärderingsmodeller som presenteras av Sandberg och Faugert (2016: 63) tillsammans med exempel på vad dessa kan motsvaras av inom konservering.

Indikatorer och måttstockar

Kriterierna i en värderingsmodell ska underbyggas med ändamålsmässiga indikatorer. Enligt Sandberg och Faugert (2016: 52) är en bra indikator allmänt accepterad i den bransch som utvärderingen avser, samt är tydlig och underbyggd med källor.

Inom konservering kan bra indikatorer hittas i litteratur om olika materialkategorier, särskilda typer av skador eller specifika konserveringsmetoder. Det kan exempelvis vara kända och oönskade effekter som kan uppkomma efter en konservering: opacitet, gulnad, förändringar i struktur, korrosion, lukt, om ett föremål förefaller styvt vid hantering, om det dammar eller lämnar andra depositioner och mycket mer. En annan typ av indikator är observerade förändringar vid jämförelse mellan ett tidigare dokumenterat tillstånd med objektets aktuella tillstånd. Dock kan det ibland vara svårt att avgöra vilka faktorer som ska tillskrivas den utvärderade konserveringen och vad som beror på annat.

Additionalitet är ett begrepp som används inom näringslivs,- innovations- och arbetsmarknadspolitik specifikt för att hantera utvärderingsfall där en effekt kan ha påverkats av annat (Sandberg & Faugert 2016: 52). Det innebär att utvärderingens måttstock utgörs av en tydlig beskrivning av vad en åtgärd har bidragit med (eller orsakat) *utöver* det som ändå skulle ha hänt. Forss (2007: 46-47) exemplifierar med en utvärdering av en biståndsinsats från Sida. Sambandsfrågan var komplex. För att hantera komplexiteten vände utvärderarna på frågeställningen. Istället för att fråga vilken betydelse insatsen haft för den observerade effekten ställdes frågan: vilka faktorer är det som har orsakat effekten? Det visade sig att Sidas insats i detta fall var en mycket liten del av de faktorer som var orsaken till effekten.

Tabell 4 (till höger). Exempel på skalor för tillståndsbedömning och konserveringsutvärdering. De flesta av dessa modeller var ytterligare understödda med skadekriterier och förtydligande förklaringar. De engelskspråkiga källorna har fritt översatts till svenska.

Skala	Källa
A. Kräver omkonservering när det gäller de undersökta faktorerna B. Kan behöva omkonservering inom snar framtid när det gäller de undersökta faktorerna C. Stabil, men skall hållas under uppsikt D. Stabil	Anderson 2010 Sammanvägd statusbedömning
A Utmärkt bindning B Lokala släpp C Mycket dålig bindning med totalt eller partiellt släpp	Marcuccio & Claudio 2006 Dubbleringsbindning
1 Mycket gott tillstånd 2 Acceptabelt tillstånd 3 Instabilt tillstånd 4 Akut tillstånd	Franzon & Glasemann 2017 Graderingssystem för tillståndsbedömning
10 Mycket gott tillstånd -- 3 Mycket dåligt tillståndw	Sully & Suenson-Taylor 1996 Sammanräknat tillståndspoäng
1 Akut. Uppenbar nedbrytning 2 Hög. Kommer brytas ner / behöver aktiv konservering 3 Låg. Behöver restaureras före utställning 4 Liten prioritet. Endast ytrengöring	Sully & Suenson-Taylor 1996 Prioriteringskoder
1 Bra. Bra tillstånd, stabilt 2. Acceptabelt. Vanprytt eller skadat, inga omedelbara åtgärder behövs 3. Dåligt. Troligtvis instabilt, kräver aktiva åtgärder 4. Oacceptabelt. Pågående nedbrytning	Taylor 2013 Graderingssystem för tillståndsbedömning
1. Åtgärdas snarast 2. Bör åtgärdas 3. Kräver ej åtgärd	Lindbom & Hermerén 2014 Prioriteringsgrupp
1. Stabil. Få tecken på tidigare nedbrytning. Inga tecken på aktiv nedbrytning 2. Tecken på tidigare och aktiv nedbrytning såsom ytaktivitet och sporadiska sprickor 3. Tecken på tidigare och aktiv nedbrytning, såsom ytaktivitet och sprickor. Ytmaterialförlust vid hantering 4. Tecken på tidigare och aktiv nedbrytning, såsom ytaktivitet och sprickor. Spontanförlust av ytmaterial eller massa 5. Total nedbrytning	Häggström et al. 2013 Klassifikationsmodell

Ett närliggande begrepp som är vanligt inom finansanalys är *kontributionsanalys*. Här undersöks i vilken mån en åtgärd har bidragit till en effekt utöver andra bidragande faktorer (Sandberg & Faugert 2016: 24-25). Ett fiktivt exempel inom konservering kunde vara en utvärdering där konservator 1 har konstaterat att samtliga 20 objekt som konserverats med en och samma metod är i mycket gott tillstånd. Konservatorn drar slutsatsen att metoden är väldigt effektiv. Här påpekar dock konservator 2 att tillståndsdokumentationen visar att inget av objekten var i särskilt dåligt tillstånd innan konserveringen. Klimatet i magasinet har dessutom varit stabilt. Det kan sägas att konservator 2 har gjort en kontributionsanalys.

En annan typ av måttstock kan utgöras av den utvärderade konserveringsåtgärdens syfte. Här utvärderas om åtgärden över tid har fungerat så som det var tänkt. Inom verksamhetsutvärdering varnar dock Sandberg och Faugert (2016: 67) för att oreflekterat använda en åtgärds mål för att värdera ett utfall, eftersom mål kan vara diffusa, orealistiska eller felaktiga.

Benchmarking är ytterligare en typ av måttstock. Sandberg och Faugert (2016: 79-80) skriver att metoden tillhör de komparativa utvärderingsmodellerna och går ut på att jämföra en verksamhet med en annan som fungerar som ”best practice”, det bästa på området. Metoden används för att systematiskt kunna lära av förebilder, och försöka förstå vad som inte har fungerat i de fall som inte nått upp till det bästa.

Klassifikationsmodell – en del av värderingsmodellen

En klassifikationsmodell kan hjälpa till att tydliggöra värderingsmodellen. De olika bedömningskategorierna sorteras och förklaras i en tabell. Klassifikationer underlättar vid undersökningar där många objekt ingår och kan öka samstämmigheten i bedömningen mellan olika personer. Klassifikationsmodeller är mer eller mindre konkreta. Exempel på en konkret skala är: 1 = Gul; 2 = Blå. Exempel på en mindre konkret modell är: 1 = Stabilt tillstånd; 2 = behöver konservering.

För att underlätta utvärderingens användbarhet för framtiden bör standardiserad terminologi användas. Däremot vore det inte lämpligt att standardisera en bedömningsskala. Olika utvärderingar har olika frågeställningar som kräver särskilt utformade klassifikationsmodeller. För att illustrera detta ges några exempel i tabell 4. Det är tydligt att ”bra” och ”dåligt” inte alltid befinner sig på samma ställe. De skalor där syftet har varit att prioritera har 1 utgjorts av objekt i sämre tillstånd. Andra skalor förefaller utgå från att A eller 1 är gott tillstånd, något som kan jämföras med att komma på första plats i en tävling. Sully och Suenson-Taylors skala (1996: 178) avviker från de övriga i det att den startar på 3 och slutar på 10. Anledningen är att varje steg utgör ett sammanräknat värde av flera bedömningskriterier.

Suenson-Taylor et al. (1999: 188) skriver i sin artikel om epidemiologiska utvärderingar att kulturarvsobjektens tillstånd sällan kan uppmätas på en *intervallskala*, det vill säga en skala med likvärdiga intervall (exempelvis centimeter på en linjal eller gram och kilon). I modeller för tillståndsbedömning används främst *ordinalskalor*, kategorier som har en definierad ordning. Det kan vara svårt att bedöma enligt sådana kategorier. Därför rekommenderar författarna *kriterieförankrade skalor* (criterion anchored scale, CARS) för utvärderingar. En sådan modell ger utvärderaren mera stöd för att kategorisera sin observation, till skillnad från tillståndsbedömningsformulär där hela objektets tillstånd ska graderas enligt sådana diffusa kriterier som bra och dåligt skick. Enligt CARS listas ett antal specifika tillståndskriterier (exempelvis ”lösa delar”, ”ytegenskaper”, ”färgförändring”). Varje kriterium graderas på en skala med två till sex steg. Vid undersökningen ska sedan poängsammanräkning för de olika kriterierna göras. De kriterier som väljs ska specifikt avse den utvärderade konserveringens effekt. De ska vara knutna till förändringstecken hos objektet, och ska inte överlappa varandra. Varje steg ska beskrivas tydligt. Inte heller stegen inom kriteriet ska överlappa (Suenson-Taylor et al. 1999: 188). Exempel på en kriterieförankrad skala ges i tabell 5.

Forss (2007: 66) skriver att en skala kan verka bedrägligt vetenskaplig, och att det ibland kan vara mera ärligt att presentera en utvärdering kvalitativt i en text. Även Suenson-Taylor et al. (1999: 189) varnar för att klassifikationsmodeller med skalor och poängsättning kan uppfattas som uppmätta kvantitativa värden, trots att de i verkligheten endast är uppordnade kategorier.

Insamling av data

Inom verksamhetsutvärdering görs datainsamlingen genom intervju, observation, enkät eller analys av dokumentation (Forss 2007: 22). I tabell 6 ges exempel på icke- invasiv datainsamling inom konservering enligt

dessa områden. Efter insamling ska informationen bearbetas och analyseras. Databearbetning är inte en värdering i sig, men här skapas underlaget till värderingen.

Varje kulturhistoriskt objekt är unikt. Vid utvärdering där datainsamlingen sker med icke-invasiva metoder och där objekten har förvarats utanför en kontrollerad laboratoriemiljö finns det otaliga

Kriterium	Poäng	Instruktion
Sammanhållning (cohesivity)	1-4	Överväg lädret på makro-skala och objektets sammanhållning. Titta på känsliga ytor där materialförlust kan ske. Ha objektets beskaffenhet och form i åtanke. 1. Många fragment som lätt lossnar under hantering. 2. Flera fragment som lossnar under hantering. 3. Mindre ytor av känsliga fragment. 4. Lädret intakt inga känsliga fragment.
Sprödhet (friability)	1-4	Diagnostisera primärt endast på ytgrängen. Viss hänsyn ska dock tas till de exponerade ytorna. Där grängyta inte längre finns ska bedömning av den kvarvarande fiberytan göras. 1. Fibrer lossnar lätt under hantering och resulterar i total ytmaterialförlust. 2. Större delen av ytan och de exponerade kanterna utsatta för materialförlust. 3. Ett fåtal grängområden utsatta för bortfall av fibrer materialförlust 4. Grängytan intakt, inga lösa fibrer.
Flexibilitet	1-2	Flexibiliteten ska fungera för objektet. Om flexibel, inte så svag att objektet kan skadas. Om oflexibel, inte så spröd att det kan skadad under hantering. 1. Oacceptabel – svag eller styv och spröd. 2. Flexibel.

Tabell 5. Exempel på CARS-modell med kriterier som är specifika för läder, enligt Sully & Suenson-Taylor (1996: 177-178). Efter bedömning ska poängen räknas samman. Fri översättning.

Datainsamlingssätt	Motsvarande inom konservering
Observation	Okulär undersökning, tillståndsbedömning, analytiska undersökningsmetoder som fotografering och icke-invasiv materialanalys.
Intervju	Intervjuer med konservatorer, förvaltare, beslutsfattare, ägare, och andra intressenter exempelvis för att komplettera information från observation och dokumentationsanalys.
Enkät	Samma som intervju.
Analys av dokumentation	Insamling och analys av bevaraderelaterad dokumentation såsom konserveringsrapporter, åtgärdsplaner, klimatmätningar.

Tabell 6. Forss fyra datainsamlingssätt (2007: 22) i relation till undersökningsmetoder inom konservering.

variabler och jämförelseparametrar. De jämförande aspekterna kan behöva begränsas beroende på datainsamlingsmetodernas begränsningar.

Sandberg och Faugert (2016: 36) varnar för att det under utvärderingen kan framkomma att bedömningskriterierna behöver ändras. Vid stora mängder data kan det vara vanskligt att ändra i efterhand. Om en konserveringsutvärdering består av att tillståndsbedöma hundratals objekt kan det vara svårt att i efterhand gå tillbaka och undersöka ytterligare en aspekt av konserveringen hos alla objekten.

Vid stora mängder objekt är rådet som ges av Suenson-Taylor et al. (1999: 185) att datainsamlingsmetoderna ska vara tillförlitliga men enkla, så att de kan tillämpas konsekvent. För komplexa frågeställningar ger Sandberg och Faugert (2016: 47) rådet att använda metodtriangulering, där flera datainsamlingsmetoder eller analysmetoder används eller där kvalitativa och kvantitativa metoder kombineras.

Okulär observation och diagnostisering

Praxis för okulära tillståndskontroller passar även för att samla in data vid utvärderingar. I en statistisk studie av reliabiliteten i okulära tillståndsbedömningar har Taylor (2013: 99) framhållit att skillnader i bedömningar kan bero på att själva ordet tillstånd betyder olika saker för olika bedömare:

- objektets stabilitet,
- angelägenhetsgraden och omfattningen av konserveringbehovet,
- objektets funktionsduglighet,
- bjektets utseende,
- noterade förändringar i olika parametrar.

Begreppet *diagnostisering* används sällan på svenska inom konservering, men definieras i den svenska versionen av standarden ”Bevarande av Kulturarv - Generella termer och definitioner” (SIS 2011: 14): ”process för bedömning av ett objekts nuvarande tillstånd och för bestämning av eventuella förändringars orsak och verkan samt slutsatser”. I praktiken särskiljs det sällan mellan okulär observation (datainsamling) och diagnostisering (databearbetning) vid tillståndskontroller. Enligt Taylor (2013: 104) är bedömningen vid en tillståndskontroll ofta en blandning av hur objektet ser ut och den innebörd som konservatorn tillskriver sin observation. Konservatorns slutledning utifrån tillståndsdata handlar om möjliga orsaker till de observerade effekterna. Sådan information finns inte latent i insamlade data. Skulle det underlätta för en mera strukturerad okulär undersökning att särskilja bedömningens delar åt: observation och diagnostisering?

Vid tillståndsbedömning av arkitekturbundna ytor kompletterar konservatorer ibland de okulära undersökningarna med taktila inspektioner. Hur känns en yta för fingrarna: sockrar, pudrar eller smular den? För ett tränat öra går det att avgöra om det finns hålrum mellan skikten i en yta genom att knacka på den. Dessa metoder är inte analytiska, men de ger viktiga indikationer om objektets tillstånd.

I Taylors (2013: 104) och Taylor & Stevensons (1999: 37-39) studier ges några råd för öka reliabiliteten vid okulära undersökningar:

- arbeta i par,
- ha ett fokuserat mål för undersökningen och tydliga ramar för informationsinsamlingen,
- en tydlig definition av tillstånd,
- en klassifikationsmodell med logisk skala och tydliga förklaringar utan överlappningar mellan skadekategorierna,
- en pilotstudie där population och metodik bestäms och träning av personal görs,
- vid omfattande tillståndsöversyner: en plan för god arbetsmiljö med pauser i undersökningspassen,
- så snabb rapportering som möjligt, eftersom tillståndsinformation är en färskvara.

Analytiska tekniker

Med hjälp av analytiska tekniker skapas mätbara värden. Inom konserveringsvetenskap finns det många exempel på analytiska icke-invasiva tekniker för att undersöka objekt. Teknikerna kan vara enkla eller avancerade, kostnadseffektiva eller dyra. Ofta krävs tillgång till laboratorier eller akademiska samarbeten. Vid rätt tillämpning kan analyser komplettera, falsifiera eller verifiera okulära bedömningar.

Icke-invasiva analytiska tekniker för undersökning av kulturarvsobjekt skulle kunna sorteras in i tre kategorier:

- visualiseringstekniker,
- punkttekniker,
- effektuppmätningstekniker.

Visualiseringsteknikerna är de som skapar en 2D- eller 3D-modell av ett objekt utifrån den insamlade informationen. Informationen samlas exempelvis in genom fotografering i olika ljus (påfallande, släpljus, UV), genom ultraljud, vid röntgen eller genom att läsa av IR- reflektionen. I avhandlingen ”Bonadsmåleri under lupp” benämner Nyström (2012: 37) sådana tekniker ”icke invasiv spektralteknik” och menar att de bör föregå andra analyser eftersom här skapas en helhetsbild av objektet som kan hjälpa till att avgöra vilka ytterligare analyser som ska utföras.

Ofta framkommer det inte i konserveringsrapporter exakt var på objektet ett konserveringsmaterial har applicerats. En undersökning med UV-lampa kan avslöja detta. Nyström (2012: 38) skriver att materialens fluorescens tenderar att öka med tiden. Recent material, exempelvis retuscher, kan uppvisa frånvaro av fluorescens.

Punkttekniker är sådana som mäter exempelvis en molekylär sammansättning i ett litet område på ett objekt, och är till exempel spektroskopiska metoder. I en sammanfattning av ett pågående delprojekt inom ett IPERION-samarbete framhåller Galeotti (2019: 18) att visualiseringsteknikerna är att föredra framför punkttekniker vad gäller utvärderingar av ytbehandlingar på metaller. Med visualiseringstekniker finns möjlighet att få ett helhetsintryck av det konserverade objektet, förutsatt att upplösningen är tillräckligt hög för det som ska undersökas.

Informationstyp	Exempel på dokumenttyp
Mätningar av miljöfaktorer	• Tabell eller graf med uppmätt temperatur och relativ luftfuktighet • Tabell med uppmätt antal luxtimmar • Rapport av luftkvalitetmätning från insidan av montrar • Karta över lokaler med zoner för estimerad risk för skadedjursangrepp
Teknisk dokumentation	Ingår ofta i olika typer av rapporter och planer men kan också utgöras av egna dokument. • Fotografier • Analysresultat • Textbeskrivningar • Karteringar
Tillståndsdokumentation	• Anteckning av en enkel kontroll av det aktuella tillståndet • Tillståndsrapport för ett enskilt objekt • Gemensam tillståndsrapport för flera objekt • Rapport av en samlingsöversyn
Konserveringsplanering	• VoU-plan • Åtgärdsprogram • Åtgärdsförslag • Förvaltningsplan • Förundersökningsrapport
Konserveringsdokumentation	• Åtgärdshistorik i objektposter i databaser • Konserveringsrapporter • Äldre fotografier
Övrig bevaranderelaterad dokumentation	• Nyförvärvsdokumentation • Packprotokoll • Transporthistorik • Försäkringsärenden

Tabell 7. Olika informationstyper som kan vara relevant vid utvärderingar av tidigare konserveringar och exempel på vilka slags dokument de kan utgöras av. De olika informationstyperna utgör inte alltid egna rapporter. En konserveringsrapport skulle till exempel kunna innehålla samtliga informationstyper.

Svahn (2006: 24-25) beskriver att kolorimetriska och spektrofotometriska metoder har använts för icke-invasiv färguppmätning på konserverad sten i utomhusmiljö. En färgförändring kan indikera att kemiska reaktioner har skett, men resultaten kan försvåras av temperaturskillnader och skillnader i fuktinnehåll i stenen. Det kan dessutom vara svårt att mäta exakt samma punkt som vid tidigare mättillfälle.

Vid workshopen ”Removal of Damaging Conservation Treatments” (Svahn Garreau 2007: 9-11) framkom ett exempel på när en analytisk teknik inte fungerat. För att undersöka hur effektiv en konserveringsmetod för att avlägsna kaseinlim från en muralmålning hade varit prövades 2D Fluorescence spectrophotometer. Instrumentet kunde dock inte detektera kaseinet. Flera försvårande faktorer föreslogs: pigmenttypen i målningen, ytans porositet, förekomst av saltutfällningar, mikrobiell påväxt eller typen och nedbrytningsgraden av kaseinet.

Effektuppmätningsteknikerna är de som mäter fenomen, exempelvis gasemissioner, konduktivitet eller vattenabsorptionskapasitet. Vid en utvärdering av hur ändringar i tillåtna klimatkrav påverkar museiobjekt undersökte Łukomski et al. (2013: 69; 72-73) ett 1700-talsskåp i en permanent utställning. Ljudemissioner (acoustic emmission) av sprickbildningen i trämaterialet övervakades under två år efter klimatåtgärden, med hjälp av mätare fästa på objektets yta. Mätarna omvandlade ljudvågor till elektriska signaler. Informationen korrelerades med museets mikroklimatmätningar och slutsatsen var att veckovisa fluktuationer i luftfuktighet accelererade sprickbildningen. Ett annat exempel är detektering av ättiksyra och myrsyra med AD-remsor (Acid Detector strips). I en experimentell undersökning av hur AD-remsor kan användas i samlingsförvaltning har Hackney (2016: 56) visat att exempelvis objekt av papper kan emittera organiska syror som kan upptäckas med AD-remsor. Effektuppmätningstekniker liknande dessa skulle kunna användas för att mäta aktiva konserveringsåtgärders effekter eller effektivitet över tid.

Intervjuer och enkäter

Intervjuer och enkätundersökningar bland konservatorer och andra intressenter kan inte ersätta undersökningar av objekt, men kan ge värdefull information om processer och orsaker till de i en utvärdering observerade effekterna. Exempelvis har såväl Nilsson (2015) som Häggström et al. (2013) genomfört enkätundersökningar för att få underlag och kompletterande information till konserveringsutvärderingsstudier.

Studier av bevaranderelaterad dokumentation

Vid de flesta utvärderingar är det en förutsättning att den konserveringsåtgärd som utvärderas på något sätt är dokumenterad. För att kunna jämföra konserveringens resultat och effekter med åtgärdens syfte och mål är det bra om åtgärdsförslaget har varit tydligt och genomförandet grundligt beskrivet.

Bevaranderelaterad dokumentation kan vara analog eller digital. I tabell 7 finns ett förslag hur olika informationstyper kan sorteras.

Det är inte bara konserveringsrapporten som kan användas vid en utvärdering av tidigare konserveringar. All tillgänglig och rimligen åtkomlig information som finns om objektet kan vara relevant. Till exempel kan mätdata av miljöfaktorer korreleras med objektens tillståndshistorik. Tidigare tillståndsdokumentation skulle kunna användas för att spåra när oönskade förändringar har skett. Ett fiktivt exempel är en utvärdering där flera objekt som konserverats med en särskild metod är angripna av skadeinsekter. Istället för att dra slutsatsen att denna konserveringsmetod ökar risken för skadedjursangrepp korreleras objektens placering med organisationens IPM-kartor. Kartorna visar riskzoner för skadedjursangrepp och det framkommer att objekten förvaras i en riskzon. I detta fiktiva exempel är placeringen en viktig parameter för förståelsen av konserveringsmetodens effekt.

Frågeställningar där många objekt ska undersökas kräver god planering av hur dokumentationen ska hanteras. Forss (2007: 90) råder att insamling, urval och strukturering samt en analys av informationens användbarhet för utvärderingen bör göras inför det att informationen bearbetas och bedöms.

Golfomitsou et al. (2017) analyserade National Trusts samlingsförvaltningssystem för att få underlag till en större studie om beslutsresonemang vid rengöringsåtgärder. Istället för att samla in data för att besvara en särskild fråga eftersöktes mönster och trender. Variationerna i formaten begränsade analysmöjligheterna och det visade sig vara tidskrävande att strukturera upp informationen för statistisk databearbetning (Golfomitsou et al. 2017: 3).

Konklusion

I den här artikeln har utvärdering av tidigare konserveringar belysts med hjälp av vedertagna resonemang inom ämnesområdet verksamhetsutvärdering.

Utvärdering av tidigare konserveringsåtgärder är att, utifrån systematiskt insamlad information, bedöma resultatet och effekten av en tillämpad konserveringsmetod i syfte att öka kunskapen om hur kulturarvet påverkas av konserveringens praktik. En utvärdering bör vara framåtsyftande och leda till förbättring av den egna eller hela konserveringsfältets praktik.

En utvärdering är till skillnad från en uppföljning värderande. Det är inte objektet i sig som värderas, utan effekterna av aktiva konserveringsåtgärder. Utvärderingsämnet kan exempelvis handla om effektens tillräcklighet, jämförelser mellan utfallet för olika metoder eller om en förändring är acceptabel eller inte. För att kunna uttala sig om effekter behöver en tid ha passerat sedan konserveringens genomförande, medan resultat från en åtgärd kan utvärderas direkt efter åtgärdens slutförande.

Vid en utvärdering är det viktigt att klargöra om motivet huvudsakligen är kontrollerande/granskande, eller lärande. Det kan hjälpa till att avgöra om det behövs externa utvärderare.

Utvärderingarnas syften kan exempelvis handla om att skapa ett underlag inför beslut om återbehandling eller att kontrollera om metoder och material har haft den önskade effekten. I sin formativa form kan utvärdering av tidigare konserveringar direkt svara mot E.C.C.O:s etiska krav på att konservatorn ständigt ska förbättra sina metoder. Syftet kan även vara att förstå de övergripande bakomliggande processerna kring konserveringsåtgärder. Om konservatorer eller beslutsfattare blickar tillbaka kan lärdom dras om den egna praktiken och de egna besluten.

En värderingsmodell bör utformats särskilt för den specifika frågeställningen. Modelltyper som tillämpas inom verksamhetsutvärdering skulle kunna göra nytta även inom konserveringsutvärdering: additionalitet, kontributionsanalys och benchmarking. Aktuella etiska riktlinjer för konservering bör guida värderingsmodellen, men värderingen ska göras enligt konkreta bedömningskriterier. Kriterierna ska underbyggas med vedertagna och källbelagda indikatorer. En klassifikationsmodell kan bidra till att förtydliga värderingsmodellen.

Utvärderingsämnet styr vilken datainsamlingsmetod som väljs. En utvärdering är mer än en tillståndsbedömning, men metodik för tillståndsbedömningar är användbar. Inom konserveringsvetenskap finns många icke-invasiva analytiska tekniker som kan komplettera okulära bedömningar vid utvärderingar av tidigare konserveringar. Få är direkt anpassade för utvärdering. Det krävs ett gott förarbete för att specificera en frågeställning så att det som mäts verkligen motsvarar utvärderingsämnet.

En utvärdering ska vara tillförlitlig (ha hög reliabilitet) och allmängiltig (ha hög validitet). Generella slutsatser om en konserveringsmetod eller ett konserveringsmaterial endast utifrån ett fåtal studerade objekt bör inte göras. För att resultaten från en utvärdering ska vara användbara i framtiden bör dataredovisningen vara öppen.

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THINK GLOBALLY; ACT LOCALLY

SUPPLEMENTARY CHECKLIST FOR SAFEGUARDING HISTORIC OBJECTS AND INTERIORS FROM EXTREME HAZARDS

Abstract

Over the last decade, there has been an increased focus on preventive work for safeguarding objects and interiors of cultural and historical importance from sudden hazards. Manuals and guides have been developed to raise awareness of how to react when a crisis strikes. However, there seems to be a gap between the developed tools and the practices at local levels. This paper aims to provide a systematic overview of effective routines for safeguarding historic interiors that normally fall outside the scope of a regular risk management plan for heritage buildings. The paper also presents an overview of relevant guides for historic interiors, which complement the already published, general guidelines for safeguarding cultural heritage. Based on the author's experiences gained from collaborative, preventive emergency projects, as well as the findings reported in the relevant literature, the paper presents a supplementary checklist of routines for safeguarding historic interiors. The role of conservators as heritage specialists is discussed, especially in situations where historic buildings are managed without heritage specialists as staff members. This article also reveals the need for further studies related to this topic.

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Keywords:
Emergency response plan; extreme hazards; cultural heritage; historic interiors, low-threshold solutions; mitigation measures; fire covers; compartmentation.

Introduction

In March 2019, the Norsk institutt for kulturminneforskning (Norwegian Institute for Cultural Heritage Research, NIKU) and the Arbeidsgiverorganisasjon for kirkelige virksomheter (Norwegian Association for Church Employers, KA) started the Agder project to deal with emergency response in three churches in Agder County, Norway. One of its aims was to find low-level, practical solutions or measures to mitigate potential fire damage to church objects and interiors. We examined how interaction between regional and national experts could be advantageous for all parties, and help develop better management of the churches, by focusing on salvage plans. An interdisciplinary working group, consisting of owners, managers, firefighters, emergency salvage teams, conservators and representatives of the municipality, visited three churches to assess the current situation and discuss scenarios, and the values of different objects, as well as other issues concerning both mitigation measures and emergency salvage work. A full-scale drill carried out in a medieval church involved testing the salvage plan using props to represent selected objects in the church. The drill was then evaluated, and the results were presented at a seminar, together with a discussion about the strategy necessary for the improvement of emergency planning. Through this collaborative project, it has become apparent that many international manuals and guides are not tailored to small cultural heritage buildings and institutions managed by non-heritage experts. Additionally, they rarely focus on preventive work to mitigate risks to the objects and interiors.

MOK

Figures 1, 2 and 3 (to the right). Fires and floods top the list of disasters affecting cultural institutions. Skaugum in Asker Municipality is a manor house and the residence of the Crown Prince of Norway, which caught fire in 1930. Photographs before, during and after the fire. Figure 1: S. Gran 1925. Figures 2 and 3: Steen and Henriksen 1930. (All photographs: Nasjonalbiblioteket www.nb.no, CC0 1.0 licence).

Two main elements are at risk from fire: the building itself and its contents. The structures of the buildings themselves may have some sort of resilience, but their contents may have none (Kincaid 2018: 3). Surface treatments, decorative paint and interior details in traditional buildings require careful consideration. In addition to acting as fuel sources, they are extremely vulnerable to damage from fire and smoke, as well as from fire suppression media, such as water or foam (Historic Scotland 2010: 29). This issue suggests an increased focus on interiors when working on preventive measures against fire and water damage. A literature review on the topic reveals a lack of attention to objects and interiors in particular.

When examining disasters affecting cultural institutions worldwide, fires and floods top the list in the period 1981–1999, followed by earthquakes and wars (Dorge and Jones 1999: 2). There is no reason to believe that this situation has changed over the last 20 years. Based on current trends, the number of disasters and their intensity are expected to rise (Meier, Will and Petzet 2007), which we have observed since 2007 (Figures 1–3). Climate change may also introduce new or intensified risks to cultural heritage assets, including heavy precipitation and rising sea levels (Stanton-Geddes and Anees Soz 2017: 3).

In the last 20 years there has been a focus on climate hazards to built cultural heritage and museum collections through the work of the International Council of Museums (ICOM), International Council of Museums- Committee for Conservation (ICOM-CC), International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM), Blue Shield, the Council of Europe, Historic Environment Scotland, Historic England and other large organisations. Thorough work has also been undertaken to raise awareness of emergency response after sudden hazards. In fact, we can say that there is an overload of guides and manuals on risk hazard analysis and emergency response (Matthews 2007: 5). Gaillard and Mercer (2012) have pointed out that there seems to be a gap between the developed tools and the practices at local levels regarding emergency preparedness. The increased importance of international treaties and manuals, and the parallel growth emphasis on community-based and local action, named ‘glocalisation’, are at the forefront of the 'need to bridge the gap' between the international and the local management (Gaillard and Mercer 2012: 94). The management of historic houses and churches might lack staff focus on fire prevention and preventive conservation, in addition to the needed focus on climate changes and surrounding geohazards. Existing national and local disaster preparedness and response mechanisms usually do not include heritage expertise in their operations (UNESCO 2021). As a result of the absence of an overview of existing literature, it could

become challenging to use international manuals and guides in their forward planning tasks.

The research questions are therefore as follows; First, how can simple preventive measures for safeguarding cultural heritage objects and interiors from water and fire be implemented? Second, what is the conservator's role in this work?

In this article, I have two aims. The first is to provide an overview of relevant international guides and papers on the subject. The second is to use the outcome of the Agder project, with the focus on fire hazards and the data obtained from my literature review to present a supplementary, simple checklist for safeguarding cultural heritage interiors from extreme hazards. The results are followed by a discussion of gaps in existing knowledge, and the conservator's role in this matter. The use of fire-protective textiles for damage mitigation is perceived as a simple and effective measure, and coverd in the literature review and the discussion.

Previous research shows that effective and robust fire safety management strategies for historic buildings allow a reduced level of physical measures (Kincaid 2012). Technical installations, including fire extinguishing systems, are outside the scope of my paper, as are plans for dealing specifically with museum collections. However, relevant information on objects and interiors, found in guides written for museums, is included.

Terminology

As far as the terminology, such as 'damage limitation', 'salvage' and 'mitigation', is concerned, I have chosen to follow Mike Coull's specifications in the Executive Summary of Recommendations under the European Cooperation in Science and Technology (COST) Action project, Built Heritage: Fire Loss to Historic Buildings (Coull 2007: 21). When describing mitigation of fire and water damage, the term 'damage limitation' is used. 'Damage limitation' is about pre-planning, consultations and having established and widely understood procedures for individual risks. This dynamic process, conducted before, during and after incidents, is a strategy with a positive and proactive approach. The term 'salvage' means the process of recovering contents and 'mitigating' damage during or immediately following intervention tactics.

A salvage plan is defined here as part of an emergency response plan. Prioritised items are described with key information to help the fire brigade salvage them with minimal damage. The salvage plan often consists of several documents, such as an inventory sheet, grab sheets and first-aid sheets for the salvaged items.

Literature review, guides and papers

The Council of Europe's report, Vulnerability of Cultural Heritage to Climate Change, lists relevant actions by international institutions (Sabbioni et al. 2008: 5). Another important document is Safeguarding Cultural Heritage from Natural and Man-Made Disasters, issued by the European Commission (Bonazza et al. 2018). These documents present a relevant overview of the topic at a systemic level, and of practical damage limitation measures to reduce the consequences of extreme hazards. As a result, these topics are not covered in this article. However, the work of COST Action C17, Built Heritage: Fire Loss to Historic Buildings (2002–2006) is relevant. The action's area of interest was objective-oriented and aimed at practical issues (COST C17 2006). As a follow-up, Guideline No. 30, Managing Fire Safety in Historical Buildings, was prepared by the Confederation of Fire Protection Associations in Europe (CFPA-E 2013). The CFPA-E guide is intended for owners, managers, caretakers and others responsible for the safety of historic buildings. The guide presents basic, simple, low-cost actions, that can be done to protect historic buildings from fire. It is a useful document when looking at the implementation of low costs fire protection concepts, fire protection measures, prevention of fire spread and that evacuation of people. Salvaging items of historical value is mentioned but not further discussed (CFPA-E 2013: 18). The checklist at the end is helpful during inspections, which should be undertaken regularly (CFPA-E 2013: 21).

Guidelines tailored to professionals are also relevant, although not easily available, for local management of historic buildings. In collaboration with ICOM, among others, the Getty Conservation Institute (GCI) has worked on this topic since the 1990s. The book Building an Emergency Plan. A Guide for Museums and Other Cultural Institutions is written for professionals working in museums and other cultural institutions (Dorge and Jones 1999). The book guides the reader through management, roles, communication and training for the staff. It also contains a set of good examples on how different museums have performed specific tasks in emergency planning. Chapter 3 of the book is particularly thorough in outlining the specific emergency plan handbook (Dorge and Jones 1999:

53). However, the aspects concerning practical details are outside the scope of the book; that is for the appointed emergency planning committee to discuss.

Another example of professional guidelines is the work of the International Federation of Library Associations and Institutions (IFLA). They have written a practical manual, IFLA Disaster Preparedness and Planning (McIlwaine 2006). Although it focuses on collection items, it provides a useful overview of actions to consider regarding prevention and protection, preparedness and response when disaster strikes, as well as how to recover from a disaster. Since the manual addresses museum staff, it makes a general contribution to planning the salvaging of items to limit the damage to collections. The EU research project, Safeguarding Cultural Heritage through Technical and Organisational Resources Management (STORM 2016–2019), provides useful insights into this broad topic. It covers the current practice for the management of cultural heritage and offers new insights into predictive models, as well as risk and vulnerability assessment, where the organisational tasks are crucial. In Kincaid's (2012) research article, he also states the need for a stronger focus on safety management dealing with historic buildings. Through research, he expresses the positive outcome of a robust safety management plan. Kincaid lists the needs for making such a robust plan, with a clear focus on roles, responsibilities and training of the management staff (2012: 27). He also emphasises the importance of making a full set of records, drawings, photographs and other information that should be stored for use in rebuilding in the event of partial or total damage.

Some institutions aim at reaching out to both professionals and non-professionals. Historic Environment Scotland has worked on heritage buildings and fire prevention by publishing Technical Advice Notes and Practitioners Guides in the years 1997–2010. Historic England and the London Fire Brigade (LFB) cooperate to reach out to owners and managers of historic buildings. They have made information easily available on the Internet (LFB 2020). Here, they state that salvage procedures will vary according to the scale of the incident, but it is a worthwhile exercise to plan for the worst-case scenario, that is, the removal of all objects. Damage control is also a key factor that should be fully considered, and ceiling artwork with the risk of being damaged by fire, smoke or water is specifically mentioned (LFB 2021: 13).

Catastrophes may lead to an increase in focus on the security of physical heritage. The loss of Norway's Fantoft Stave Church in the 1992 fire initiated the financial support by the Directorate for Cultural Heritage in Norway to work on fire prevention, protection and safeguarding of the stave churches. The work has intensified the directorate's awareness of fire risk and placed fire protection higher on the agenda for protection of built heritage in Norway. For its part, the Riksantikvarieämbetet's (Swedish National Heritage Board) work on the topic has (among other things) resulted in a handbook for emergency planning and salvage rescuing (Nilsen 2016). It is inspired by a similar handbook from The National Trust (2006) in England and Wales. The Swedish handbook contains checklists to minimise the risks and be prepared for a catastrophe. The need for plans and drills is also mentioned.

Several of the reviewed articles and books emphasise the need for emergency planning. Unfortunately, many reports, guidelines and articles take this issue no further than recognising, mentioning or discussing the requirements. Seldom does the literature answer these complex matters thoroughly, and there is a lack of focus on objects and interiors, apart from museum collections. This shows the gap between international guidelines and the needed information for owners and managers of historic buildings at the local level.

The use of fire-protective textiles for damage mitigation

The use of fire-protective textiles to limit the damage to objects and interiors is a topic of discussion by people working on the protection of Norwegian cultural heritage. However, scant international research and literature highlight the use of such textiles, whether they are covers, blankets or curtains (Kjølsen Jernæs 2020: 9). The use of textiles for sectioning off a room and manually covering a specific object or part of an interior is only briefly mentioned in the literature concerning the general protection of historic buildings and cultural heritage (Kjølsen Jernæs 2020: 10) (Figure 4). Research on the effect of such coverings is not reported. Takahashi (2019: 3) writes about the knowledge gap in fire blankets: "The literature on fire blankets is scarce probably because the basic research has not been fully conducted and the R&D [research and development] efforts have mainly been made sporadically at the manufacturers without the dissemination of test results other than the specifications of final products".

Figure 4. “Brand in de lijnbanen op de schans aan de Smallepadsgracht, 1680”, showing the use of fire-protective textiles for mitigating the fire damage to whole buildings in the Netherlands. Etching/engraving by Jan van der Heyden 1690–1735. Collection by Rijksmuseum (CC0 1.0 licence).

Devi and Sharma elaborate on different passive protection measures in heritage museums and libraries (2019: 4–5). They mention different systems of smoke curtains that can be used effectively, depending on the building. Likewise, Hodžić and Džidić (2018) explain the use of curtains as fire barriers.

The handbook published by Riksantikvarieämbetet mentions the need for a fire blanket as a required item (Nilsen 2016: 87). Another example of a lsimple damage limitation measure is the use of tarpaulin or a similar material for protection in situ if a priority object is too heavy or too large to remove (Historic England 2017: 28). But how to proceed further regarding handling properties and gaining more knowledge from tests and experience?

Some independent, small-scale tests on covering or wrapping items in case of fire in a museum or a cultural heritage building have been undertaken (Kjølsen Jernæs 2020: 11), but the results have not been published yet. However, when reviewing the use and the effect of fire-protective textiles, the general professional position seems to be that such textiles should be considered when the total risk and preventive measures are being evaluated. There is a need to consider the effects of different coverings and curtains as part of the total risk and vulnerability assessment.

The supplementary checklist

The guides and manuals mentioned provide a n overview of prevention, risks, preparedness, response and recovery at different levels. At the planning level, there is a predominance of instructions for systems and emergency plans. Apart from Guideline No. 30 by the CFPA-E (2013) and the work done by Historic Scotland (2010), Historic England (2017) and LFB (2020), most of the other documents are more suitable for the staff in medium to large museums than the personnel in small countryside museums, historic houses or castles, churches or open-air museums. The checklist in Table 1 supplements the GCI’s guidelines, Chapter 3, which deals with emergency planning in Steps 1–7 (Dorge and Jones 1999: 53–76), as follows: 1) assess the hazards, 2) identify assets and vulnerabilities, 3) implement preventive measures, 4) implement planning measures, 5) develop the response plan, 6) develop/ salvage procedures and 7) write the emergency plan. The checklist supplements the work in Steps 2 and 3.

Checklist
1. Normal maintenance of building structure No: Consider starting with normal maintenance. Yes: Start working on the checklist for the interior.
2. Laws and regulations on technical prevention Not followed: Do this first. Followed: Start working on the checklist for the interior.
3. Overall safeguarding Obtain local climate projections. Hazards to your building – part of the risk and vulnerability assessment. Link this to your municipalities' disaster risk-reduction plans.
4. Collect relevant information and documentation. Is the interior painted, or does it have wall tapestries? Collect information about the materials and the history of the decorated surfaces, and the building in general. Some surfaces might be water sensitive, and the documentation would serve as the basis for finding appropriate damage-limiting measures, in addition to being crucial after partial or total damage.
5. Rooms and zones Are there any rooms or zones with particularly valuable interiors or that have a large concentration of valuable items? Mark these areas as priority zones that the fire brigade should protect, to prevent the fire from reaching them. Fire curtains might function as compartmentation.
6. Dismantling Can parts of the interior be dismantled? How? Examine how the objects/interior parts are mounted. Could their mounting be improved to facilitate possible dismantling/salvaging? Describe appropriate equipment and tools for large items secured to the wall/floor. Are some parts less important than others and can be sacrificed if needed? Discuss the need for fire-protective covers and/or covers to limit water damage to objects that cannot be salvaged. If uncertain about the proper dismantling procedure, invite the local fire brigade and a conservator or another expert on art, construction and materials for on-site consultation.

7. Location Location that is safe from theft, with possibility for salvage. Check if the location is cluttered with valuable items. Avoid places with risk of water damage. Have a plan for storage of salvaged items and the required materials and equipment (covers/ tarpaulins, ladders, etc.).
8. Make an emergency response plan. The above-mentioned issues need to be discussed in interdisciplinary groups. Create an opportunity for dialogue with the local fire brigade and heritage experts/conservators. Go through the building, discussing different scenarios. Discuss the items and the interiors – what are the possibilities and the limitations regarding the prioritised objects?
9. Records, drawings, photographs and other information should be stored offsite for use in rebuilding in the event of partial or total damage.

Table 1. Practical checklist for safeguarding historic interiors.

It is also relevant to read this checklist in the light of the CFPA-E (2013) guide on low-level adaptations for historic buildings.

The practical checklist starts with Steps 1–3 to ensure that normal maintenance is carried out, a broad risk and vulnerability assessment is undertaken, and laws and regulations regarding fire safety in public buildings are followed. Identifying undesirable incidents is an important part of the introductory work (Kulturrådet 2015: 5). However, in a typical risk and vulnerability assessment, it may be irrelevant to discuss the probability of occurrence of extreme incidents and their consequences. In assessing interiors and objects that are irreplaceable, the worst consequence might be unacceptable despite its low probability.

Normal maintenance is a good way of preventing both small- and large-scale damage, as well as extreme hazards. Linking this work to the municipalities' disaster risk reduction might be challenging. In its Research, Vestlandsforskning (Western Norway Research Institute) states that knowledge concerning extreme climate challenges needs to be strengthened at local levels, and adaptation strategies should be made more locally relevant (Rusdal and Aall 2019: 35). Step 4 opens a discussion on the details of the interior. Does the interior have decorated ceilings or walls? There might be challenges, such as the fire brigade needing to use the roof to let out smoke and rig for the fire hoses, damaging a painted ceiling (Figure 5). In general, the important parts or pieces cannot be covered or salvaged. To be prepared for the worst-case scenario, painted walls and ceilings should be documented with high-quality photographs, together with thorough descriptions of the materials, techniques and motifs. This will enable reconstruction or copying the decoration or the wallpaper after any damage (see Step 9). As Kincaid lists in his overview of the needs for a robust risk management plan, the records, drawings, photographs and other information on the whole building should be stored offsite for use in rebuilding in the event of partial or total damage (2012: 27).

Step 5 involves consideration of rooms, compartmentation and priority zones. Independent of where the situation occurs inside a building, the work group could identify priority zones which the fire brigade should attempt to prevent fire from reaching. Historic England suggests that in each zone of the building, a maximum of three items should be prioritised in salvage work (2017: 27). In some buildings, especially in churches, the setting

Figure 5. Mykland Church in Froland Municipality, with decorated ceilings (1931) by Torkild Gill. This is a typical example where documentation prior to a damage is crucial (as stated in Step 4). Photo: Nina Kjølsen Jernæs (2019).

and placement of items cannot always be changed or moved. It is important to consider flexibility when examining different risks. The fire brigade should be able to adjust the salvage plan according to the situation.

Step 6 involves decisions regarding dismantling of large and/or mounted objects. Through the Agder project, it has become apparent that in most cases, the fire brigade lacks the necessary information on dismantling parts of historic interiors if this is not spelled out in a salvage plan. Experiences from earlier fires in historic buildings without salvage plans reveal two types of outcomes. On one hand, some fires have resulted in salvaging of items because the key people onsite have given the relevant information to the fire brigade. On the other hand, sometimes the result is that the fire brigade does not have a salvage plan or enough information about heritage values, priorities and practical guidance, and the firefighters do not risk going inside a building to start searching and salvaging. Otherwise, they would put their lives at stake for an uncertain outcome. The building with its objects and interior may then be lost.

In some cases, an examination the different parts of the objects is needed. Perhaps the sculpture that forms part of the altar piece could be easily removed. Detailed information on how to dismantle the prioritised parts is necessary. Firefighters would probably not do this operation without it being explained beforehand by a heritage expert or those responsible for the interior. There might be a need for advice from conservators or heritage specialists when considering these questions. An operation like this might also require the identification of specific tools, which could be stated in the salvage plan.

If dismantling is not possible, an alternative is to provide effective coverings for some prioritised objects. If fire-protection covers have to be used in a mitigation and salvage operation, this should be thoroughly considered by looking at the total risk and damage limitation measures. Should the cover protect the object from radiant heat, direct fire, soot, water or hopefully, several of these destructive threats? In some cases, it is effective to cover an object as part of the building's closing routines, while in other cases, it would be better if the covering could be done by the firefighters. If so, this should be specified in the salvage plan. The covers should be placed in an area where they would be easy to find, for example, where the alarm panel is situated.

Regardless of which discussions are the most relevant for each historic house, an inspection is always a good idea. This could result in constructive discussions between the management, the person responsible for checking the alarm systems, the users of the building (if relevant), the local fire brigade and a conservator or another expert on art, heritage, construction and materials.

Step 7 involves the location of items in the interior. It is always a balancing act between securing smaller items from theft and making them easy to salvage. If the building has a safe with valuable items, which is typical for churches, how long the safe can withstand fire should be checked and compared with the response time of the local fire brigade. The emergency rescue plan should provide information about the need for cooling of the safe.

The salvage plan should specify if below the ground floor, there is a cellar or a room (especially in churches) with valuable items or important cultural heritage objects. The information is crucial in case of a flood, fire or water leakage. Soon after a fire, this is an area that should be checked for the fire-extinguishing water.

There may be a possibility for the safe placement of items in rooms with suppression of sprinkler systems (FAIC 2020, Arvidson 2006: 49–51, Fällman and Hansing 1997: 71, Kidd 1995: 11), where optimal coverage from water damage should be taken accounted for. Here again, an overall assessment of values, risks and possible damage limitation measures should be undertaken. However, there is always a possibility of water damage from both fire-extinguishing water and incorrectly triggered systems to be aware of. Arvidson (2006: 51) concludes with the need for additional investigation relating to water exposure and damage from the water spray set against the corresponding fire damage. An assessment of needs to limit both these types of damages is therefore essential.

An important part of the damage limitation work for salvaging is a plan for where to place salvaged items. The plan should provide clear instructions on where the items should be placed, how they should be protected from new risks (e.g., theft or precipitation), and temporary storage. Required materials should be available, and necessary arrangements should be made beforehand.

Step 8 entails making the salvage plan. All issues listed here are of value when an extreme hazard hits a heritage building. The salvage plan is part of the overall emergency response plan and includes details regarding the protection of each prioritised object and damage mitigation.

Discussion and knowledge gaps

Reviewing the available information on caretaking of cultural heritage items in an emergency shows a gap between the developed tools and the practices at the local level. The work on which this paper is founded reaches out to bridge this gap. However, it can be argued that important work is done at local levels, of which I am unaware. Therefore, it should be mentioned that Oslo brann og redningsetat (Oslo Fire Brigade, OBRE) has worked on the limitation of damage to historic buildings over the last few years. The brigade perceived the need for a systematic way of working with salvage plans and made a template for owners and the management of museums and historic houses (Björklöf 2020). It can be used by anyone who finds it relevant. Different fire brigades will face the same layout, and the management executives of museums and other historic buildings know the necessary level of details. In collaboration with Bergen brannvesen, KA and NIKU, OBRE has made a template for churches as a spinoff (KA 2021). The supplementary checklist presented in this article can function as a tool for completing a salvage plan. Hopefully, in the future, more detailed, published information on protecting and salvaging interior is obtained, that will reach out to the heritage community.

When working with salvage plans, there are likely issues that presents uncertainties. There are complex matters to consider, some of which are likely to occur across many professions and management levels. Regarding the textile covers, there is not sufficient knowledge about the materials' direct effect on fragile objects yet. This involves gases and chemical reactions that might affect the objects, in addition to the differences in the handling properties of the various products. There is a need to study how to prevent damage from both water (flooding and fire-extinguishing water) and fire when considering the use of protective covers. More knowledge on the use of fire blankets/curtains and water covers in extreme situations is required. The handling properties of the covers, as well as the effect of the actual situation, are crucial.

It is known that compartmentation with fire-resistant textiles is used in museums and libraries, but their use in historic buildings and churches is unknown. When considering different risks and suitable damage limitation measures, economy is also part of the picture. Even if these types of measures are known to be effective and can play an important part of the total preventive picture, some work remains to be done to find good solutions for manual or automatically controlled curtains for compartmentations. Surveys and tests should be undertaken to check out how compartmentation can be incorporated in a historic building for safeguarding the valuable objects and interiors with as little intervention in the original materials as possible. The effect of mounting objects in large rooms, such as those in a church, should also be investigated.

There seems to be much to gain by improving cooperation among management levels, different professions and museums. Multidisciplinary and multi-institutional working groups, such as "Kriseressurssamarbeid for kulturinstitusjoner i Oslo og Akershus/ The crisis resource cooperation for cultural institutions in Oslo and Akershus" (KKOA) and the "Forum for kriseberedskap og restverdiredning for kunst og kulturminner /Forum for emergency preparedness and salvage rescue for art and cultural heritage" (FORK) in Norway, are already discussing these issues. Perhaps an international platform for discussing these issues would be beneficial for sharing knowledge and experience.

The existing international guides and handbooks can be refined, combined and further developed to target people working on damage limitation measures for historic buildings. There is a need to link preventive measures for historic buildings closer to the risk and vulnerability assessments carried out by the municipalities. The focus on the municipalities and their role in and responsibility for preventive work due to climate changes is being intensified. Riksantikvaren in Norway is working on a new climate strategy in the cultural heritage sector. Hopefully, this can link the preventive work for safeguarding historic buildings closer to the overall work of each municipality. From the firefighters' perspective, it does not matter who owns the building; they act on all incidents in their area of responsibility to save lives and valuable items. Therefore, it is crucial to have a holistic approach to limit the damage to the cultural heritage, setting aside the type of institution and focusing on caring for irreplaceable objects and interiors.

The conservator's role

In this article, I have focused on reaching out to the management of heritage buildings that lack heritage professionals. Sometimes, the owner or the manager, or both, struggle to obtain the necessary overview to make sufficient emergency rescue plans, including salvage plans. What knowledge and experience can conservators assist with in these cases?

Conservators can contribute with knowledge of importance while discussing different possibilities and limitations at a detailed level in dialogues concerning materials and vulnerability, mounting and possible new ways of mounting, dismantling and handling (Figure 6). However, it is not a good idea to contract out the entire work to consultants. There is a definite need to anchor the work on emergency response plans and salvage plans locally. All experience dictates that the knowledge, understanding and ownership are acquired through working with the plans.

Figure 6. There is much to gain by discussing the interiors and possibilities for salvaging with local management, firefighters and conservators. This photo shows an emergency response meeting in Ringsaker medieval church, Ringsaker Municipality. Photo: Nina Kjølsen Jernæs (2020).

Conservators can be the expert resources who help answer the difficult questions prior to a situation. Is it acceptable to use a saw for cutting the doors off a triptych? How can the mounting of prioritised objects be improved so they can be salvaged? How should a prioritised object be handled if its material or construction is fragile? A firefighter should not and would not make these decisions in an actual emergency. There is a strong possibility that nothing will be done if there are uncertainties regarding the value of an object/element and how it should be dismantled.

As mentioned, there is an abundance of relevant, theoretically based information related to disaster risk management for the cultural heritage sector. Conservators could constitute a link between theory and practice when planning for damage limitation measures. The United Nations Office for Disaster Risk Reduction (UNDRR) has launched the Words into Action (WiA) series, comprising guidelines based on global expertise, communities of practice and networks of disaster risk reduction (DRR) practitioners (Rose et al. 2020). The guidelines provide practical, specific advice on implementing a people-centred approach to DRR in line with the Sendai Framework for Disaster

Risk Reduction 2015–2030 (Rose et al. 2020). As the nature of the conservation profession is a mix between theory and practice, conservators have a role to play in preventing damage to objects, interiors, and buildings from extreme hazards. As specified by the UNESCO (2021), existing national and local disaster preparedness and response mechanisms usually do not include heritage expertise in their operations. Conservators can contribute to fill this gap.

The Agder project has revealed difficulties for owners and management without access to heritage or art history expertise when making value-based assessments. Assessing the cultural value of interiors and objects is important in making a well-founded priority list of objects to be salvaged. Conservators and art historians can provide crucial assistance when assessing the cultural heritage value, thus enabling the owner or the local management to successfully make a prioritised list of items for salvage.

Conclusion

There are numerous manuals and guidelines for emergency response in cases of built cultural heritage. Many of them could be adjusted, with the aim to facilitate their use at the local level for management without cultural heritage expertise. Important initiatives, such as COST Action C17 (2006) and the works undertaken by Historic Scotland (2010) and the cooperation between Historic England and London fire brigade (Historic England 2017, LFB 2020), need to be conveyed across borders, so owners and managers of small cultural heritage buildings and institutions could have easy access to them. It is crucial to strive for closer cooperation between the fire brigade and cultural heritage experts, as well as link the important work done across national borders. Relevant information on climate hazards and preventive measures at the municipality level should be available and relevant for owners and managers of cultural heritage buildings.

Existing guides for emergency preparedness plans lack detailed information on how to deal with historic interiors. Regarding climate changes and its impact on historic interiors, much has been written about their slow degradation and damage. How to avoid or limit the impacts of climate change and of catastrophic damage from sudden hazards seems to be a disregarded topic. Additionally, measures for limiting damage to buildings in general lack the needed focus on interiors. In this paper, I have presented a practical checklist of routines for safeguarding cultural heritage from fire and water hazards, focusing on the interiors. Hopefully, it will contribute to raising awareness of which low-threshold preventive improvements can be implemented to save cultural heritage interiors and will serve as a checklist to supplement the guidelines published by the GCI (Dorge and Jones 1999: 53–76). In this work, the role of conservators is essential, although the focus should be on local anchoring and ownership. The need for conservators' knowledge on materials, mounting, vulnerability and possible risks has been discussed in this article. The natural bridge between theory and practice in the conservation profession would help in the process towards a salvage plan based on constructive discussions and realistic scenarios. However, there is a clear need for more research on specific practical solutions regarding protective textiles, as well as testing handling properties and how different products perform during fire/water leakage. Additionally, there is a crucial need for knowledge sharing when working with mitigation and consequence-reducing measures at local levels.

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ERSTATNINGSPRODUKTER FOR MALING I NORGE UNDER VERDENSKRIGENE

Sammendrag

I første halvdel av 1900-tallet i Norge var linolje det viktigste bindemidlet i hus- og dekorasjonsmaling. I forbindelse med verdenskrigene 1914-1918 og 1939-1945 ble imidlertid linolje vanskelig tilgjengelig. Artikler og reklame publisert i tidsskriftet Maleren i perioden 1914-1945 ble studert for å undersøke konsekvensene for malerfaget av den begrensede tilgangen til linolje. En rekke nye produkter, både alene og i blanding med tradisjonelle materialer, ble tatt i bruk i forbindelse med krigene. Kvaliteten på de tilgjengelige malingsproduktene varierte mye. Mange viste seg uegnet, men intens forskning i krigstid førte også til stor kunnskapsutvikling og produksjon av nye anvendelige materialer i mellomkrigstiden og etter andre verdenskrig. Artikkelen presenterer funn som viser malingsutvalget i denne komplekse tiden og gir viktig informasjon om malte overflater, særlig i interiører, i første halvdel av 1900-tallet. Hovedfokuset er på Norge, men studien støtter seg på beskrivelser av situasjonen i Norden og informasjon om malingsproduksjon i andre land, hovedsakelig USA og Tyskland.

Abstract

In the first half of the 20th century in Norway, linseed oil was the most important binder in house and decorative paints. In connection with the world wars 1914-1918 and 1939-1945, however, linseed oil became difficult to obtain. Articles and advertisements published in the journal Maleren in the period 1914-1945 were studied to investigate the consequences for the painting profession of the limited access to linseed oil. Several new products were used in connection with the wars, both on its own or mixed with traditional materials. The quality of the available paint products varied a lot. Many proved unsuitable, but intense research in wartime also led to great knowledge development and production of new useful materials in the interwar period and after World War II. The paper presents findings that show the paint products available in this complex period and provides important information about painted surfaces, especially in interiors, in the first half of the 20th century. The focus is on Norway, but the study is based on descriptions of the situation in the Nordic countries and information on paint production in other countries, especially the USA and Germany.

Introduksjon

Maleryrket er utsatt for de samfunnsforstyrrelsene som oppstår i krigssituasjoner. Under første og andre verdenskrig økte prisen på linolje, det primære bindemidlet for maling, på grunn av liten import. Linoljen ble etter hvert rasjonert og utilgjengelig for de fleste. Under første verdenskrig erfarte man et behov for erstatninger i malingsproduksjonen, og i mellomkrigstiden startet en forrykende utvikling av lakk- og malingsprodukter. Før første verdenskrig brukte man stort sett naturlige polymerer som bindemiddel mens fra første verdenskrig og fremover startet utviklingen av oleumsbaserte, syntetiske bindemiddel. I den samtidige litteraturen blir de ofte kalt kunstharpikser.

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Nøkkelord:
Materialkontroll; celluloselim; kunstharpiks; celluloselakk; fiskeolje; emaljemaling; surrogatolje; linoljerasjonering.

Keywords:
Material control; cellulose adhesive; synthetic resin; cellulose lacquer; fish oil; enamel paint; surrogate oil; rationing of linseed oil.

MOK

Denne artikkelen gir en oversikt over bindemidlene og malingsproduktene fra tidlig 1900 til ca. 1950 og omtaler viktige endringer i produksjonen og bruken av husmaling i Norge og Norden under verdenskrigene. For å kunne forstå utviklingen i Norge, er de viktigste internasjonale teknologiske nyvinningene for bindemidler fra første halvdel av 1900-tallet presentert. Artikkelen har fokus på organiske bindemidler og interiørmalinger. Situasjonen for malerfaget og tilgangen på materialer er presentert i inndelte perioder; tidlig på 1900-tallet, under første verdenskrig 1914-1918,[1] mellomkrigstiden 1918-1939, under andre verdenskrig 1939-1945 og perioden rett etter andre verdenskrig.

Målet for studien som artikkelen er basert på, er å undersøke konsekvensene av den begrensede tilgangen på linolje, finne ut hvilke andre bindemidler og malingsprodukter som ble tatt i bruk, hvordan de ble brukt og hvilke følger det kan ha for tilstanden på malte flater som er bevart i dag. Forskningen gir bakgrunnsinformasjon for videre materialundersøkelse og behandling av malingslag fra perioden som fortsatt står i bygningene. Det er et mål at artikkelen skal kunne nyttes som kilde til materialkunnskap for de som arbeider med malingsoverflater i historiske bygninger.

Kilder

Artikkelen har hentet informasjon fra datidens tidsskrifter og brosjyrer, og fra internasjonal og nordisk litteratur, som omhandler malematerialer. Tidsskriftet Maleren, med artikler og annonser om materialer og tilgjengelighet og bruken av materialene, er den viktigste primærkilden. [2,3,4] En del av artiklene fra Maleren er gjengivelser fra artikler i lignende malertidsskrift i Danmark og Sverige.

Gjennomgangen av publikasjoner om periodens nye bindemidler danner grunnlaget for å forstå hvilke typer malingsprodukt som presenteres i annonsene i Maleren og i annet reklamemateriell fra perioden. En viktig publikasjon er Harriet Standevens House paint (2011), som viser historien og bruken av husmaling fra 1900 – 1960 i USA og Storbritannia, med fokus på utviklingen av bindemidler. Alf Johanssons bok Svensk färgindustri under 200 år (2004) ser på malingsproduksjonen, satt i en bred sosialhistorisk kontekst. Denne er viktig fordi Sverige og Norge har likheter i bygningsmassen og med hensyn til tilgang på råmaterialer til maling. Bøkene om Alf Bjerckes fabrikker av Richard Bjercke (1955) og om Jotun av Torstein Bryn (1997) beskriver utviklingen av maling- og lakkproduksjon i Norge. Publikasjon Malerfagets historie av Helge Bibow (1958) presenterer nye materialer som fikk betydning for malerfaget i perioden. Johs. Brennas Lakkhistorie (1989) viser lakkenes utvikling i den aktuelle perioden.

Maling tidlig på 1900-tallet

Linolje var den viktigste av de tørkende oljene brukt som bindemiddel i husmaling og dekorasjonsmaling tidlig på 1900-tallet. Det var også vanlig å tilsette myke eller harde naturlige harpikser i oljen. Som tynningsmiddel brukte man vegetabilsk terpentin. Andre viktige produkter var standolje og skjellakk, kasein, hornlim og såkalt «islandsk mose» (Bibow 1958). Også andre tørkende oljer ble brukt i malingsproduksjon. For eksempel ble både tung-, solsikke- og hampolje brukt i den kommersielle fabrikasjonen av oljelakker (Alf Bjerckes ferniser 1915). For utendørs maling var det en lang tradisjon langs kysten med å bruke lokalt produsert tran[5] (Olstad 2009).

På slutten av 1800-tallet ble ferdigblandet husmaling introdusert i USA og Storbritannia, og fra de første tiårene av 1900-tallet fantes det ferdigmalinger for alle formål (Standeven 2011). Både emaljemalinger som norskproduserte «Japonol», matt oljemaling som «Sani-Flat» (USA) (Fig. 1), og såkalt vaskbare vannmalinger som «Duresco» (Storbritannia) var tilgjengelige ferdigmalinger for innendørs bruk i Norge fra før første verdenskrig.

Figur 1. Annonser for «Sani-Flat» interiørmaling dukket opp jevnlig i Maleren fra begynnelsen av 1900-tallet. Foto: Wedvik.

Tungolje, også kalt kinesisk treolje, ble et viktig råstoff for malingsproduksjonen. Oljen tørket svært raskt og dannet en hard film (Standeven 2011). I Norge var tungoljebaserte produkter produsert av Alf Bjerckes malingsfabrikk allerede veldig populære

før første verdenskrig. Disse inkluderte blant annet «Oxanolje» (Fig. 2-3) og emaljemalingen «Decorin» (Fig. 4), men utover i første verdenskrig ble også tungolje utilgjengelig (Maleren 1918d; Bjercke 1955).

Figur 2. Tungoljebasert «Oxanolje», på malingsmarkedet fra 1913. Udatert. Eier/foto: Jotun Informasjonssenter.

Erstatningsprodukter under første verdenskrig 1914-1918

Ifølge Maleren varte linoljenøden, på grunn av første verdenskrig, fra 1917 til 1919. Det var også mangel på terpentin (Maleren 1939d). I 1917 sendte Industriforsyningsdepartementet ut et direktiv for bruken av maling (Fig. 5) (Maleren 1917).

Malerne ble oppfordret til å bruke vannbasert maling på vegger og tak, og fabrikkproduserte emaljemalinger til vaskbare overflater (Maleren 1918a). Gjennomgangen av annonser i Maleren viser at det kom en rekke såkalte «surrogater» til salgs (Fig. 6). Linoljen ser i stor grad ut til å ha blitt erstattet av emulsjoner. Emulsjonsoppskrifter med tradisjonelle bindemidler som dyrelim, tran, harpiks, stivelse, mel og kasein ble presentert. Det kom også en del såkalte «emulsionsstoffe» på markedet (Maleren 1918e). Norskfabrikkerte emulsjoner og emulsjonsmalinger var tilgjengelige gjennom den første verdenskrigen, som for eksempel «Hydratin» fra Alf Bjerckes fabrikk (Fig. 7).

Behovet for bindemidler inspirerte til kreativ bruk av lokale og nasjonale ressurser. Ifølge en artikkel i Maleren bestod mange surrogatoljer og -malinger i større eller mindre grad av sulfittlut (Maleren 1918b). Sulfittlut var et biprodukt fra celluloseindustriens

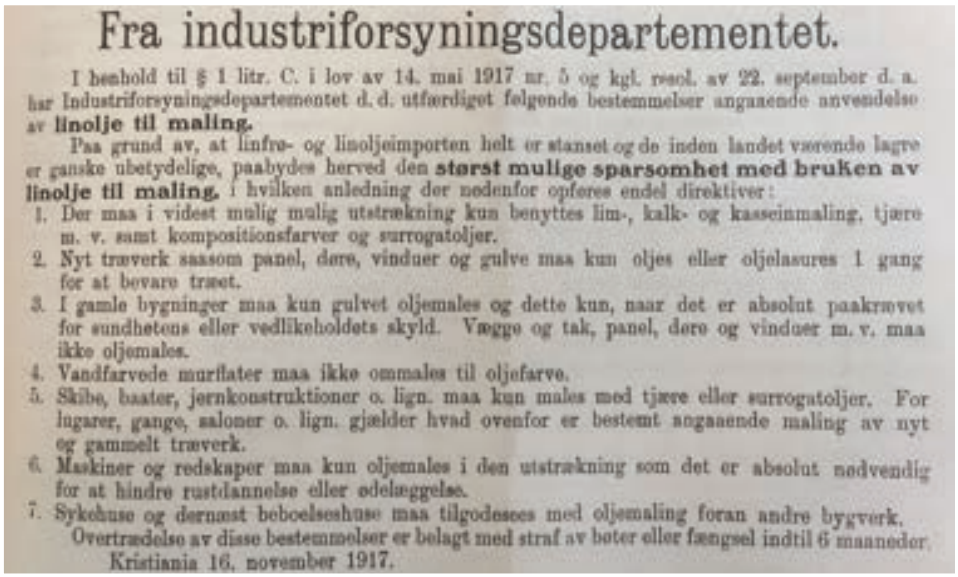

Linolje
Oxanolje

Det er vanskelig at skaffe tilstrækkelig av linolje for tiden. Derimot kan oxanolje endnu erholdes i rimelige mængder. Oxanolje gir klæbefri og sterkere maling end linolje til gulver, dører, vægger, møbler og redskaper. For utvendig maling kan den halvblandes med tran eller hvalolje og gir da en usedvanlig holdbar maling til rimelig pris. Oxanolje kan ogsaa blandes i ethvert forhold med linolje, som derved blir sterkere at slite paa. Oxanolje er derimot mindre egnet til lavning av spartellarve. Oxanolje leveres i blank og i matt kvalitet. Naar intet særskilt forlanges leveres blank. Matt oxanolje koster det samme som linolje, blank 10 øre mer pr. ltr. (kg.). Oxanolje faaes hos de fleste handlende der fører malervarer.

Alf Bjercke's Farvehandel.
29 Skippergaten 29.

Figur 3. Om linolje og «Oxanolje». Udatert. Eier/foto: Norsk Teknisk Museum.

Figur 4. Emaljemalingen «Decorin», på markedet fra 1906. Udatert. Eier/foto: Norsk Teknisk Museum.



Fra industriforsyningsdepartementet.

I henhold til § 1 litr. C. i lov av 14. mai 1917 nr. 5 og kgl. resol. av 22. september d. a. har Industriforsyningsdepartementet d. d. utfærdiget følgende bestemmelser angaaende anvendelse av **linolje til maling.**

Paa grund av, at linfrø- og linoljeimporten helt er stanset og de inden landet værende lagre er ganske ubetydelige, paabydes herved den **størst mulige sparsomhet med bruken av linolje til maling,** i hvilken anledning der nedenfor opføres endel direktiver:

1. Der maa i videst mulig mulig utstrækning kun benyttes lim-, kalk- og kasseinmaling, tjære m. v. samt kompositionsfarver og surrogatoljer.
2. Nyt trævverk saasom panel, døre, vinduer og gulve maa kun oljes eller oljelasures 1 gang for at bevare træet.
3. I gamle bygninger maa kun gulvet oljemales og dette kun, naar det er absolut paakrævet for sundhetens eller vedlikeholdets skyld. Vægge og tak, panel, døre og vinduer m. v. maa ikke oljemales.
4. Vandfarvede murflater maa ikke ommales til oljefarve.
5. Skibe, baater, jernkonstruktioner o. lign. maa kun males med tjære eller surrogatoljer. For lugarer, gange, saloner o. lign. gjælder hvad ovenfor er bestemt angaaende maling av nyt og gammelt trævverk.
6. Maskiner og redskaper maa kun oljemales i den utstrækning som det er absolut nødvendig for at hindre rustdannelse eller ødelæggelse.
7. Sykehuse og dernæst beboelseshuse maa tilgodeses med oljemaling foran andre bygverk.

Overtrædelse av disse bestemmelser er belagt med straf av bøter eller fængsel indtil 6 maaneder.

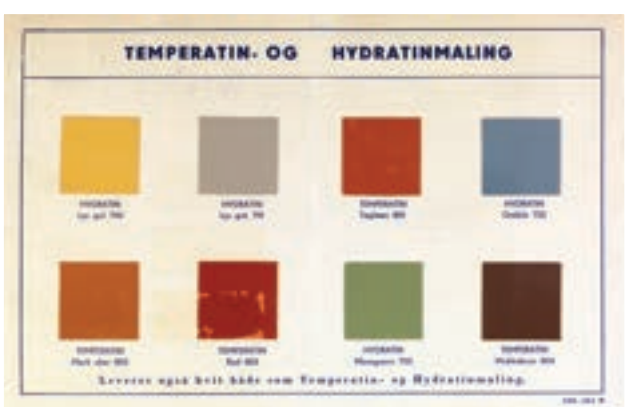
Kristiania 16. november 1917.

Figur 5. Linoljedirektivet. Maleren 1917. Foto: Wedvik.

Prima Surrogatolje

Kemisk Fabrik „Monopol" Bergen.

Figur 6. «Prima Surrogatolje». Det ble gitt lite informasjon om surrogatproduktene i annonsene. Maleren 1919. Foto: Wedvik.



Figur 7. Den ferdiglagede emulsjonsmalingen «Hydratin» var tilgjengelig gjennom første verdenskrig, mens «Temperatin», som inneholdt linolje, forsvant. Udatert. Eier/foto: Norsk Teknisk Museum.

sulfittprosess ved tremasse- og papirproduksjon. Det fantes i store mengder og var lett tilgjengelig. Tran, som i utgangspunktet er en halvtørkende olje, ble viktig når linoljen manglet. Tran ble brukt alene eller i kombinasjon med andre bindemidler (se Fig. 3) (Maleren 1918c). I 1918 ble igjen hvalolje, som en tid hadde vært regulert til næringsformål, gjort tilgjengelig for malingsproduksjon (Larsen 2012). Hvaloljen ble blandet med terpentin og lakk (Maleren 1939d).

Produkter fra den moderne malingsindustrien, som ferdige emaljemalinger fra innland og utland, var tilgjengelige gjennom hele første verdenskrig. Emaljemalingene kunne være laget med kun oljebindemidler som linolje (også standolje) og tungolje, eller med olje iblandet naturlig harpiks (Standeven 2011).

Malingens utvikling i mellomkrigstiden 1918-1939

I mellomkrigstiden var det store sosiale endringer som påvirket malernes arbeidsmarked. Boligenes representasjonsrom forsvant mens egne kjøkken- og baderom kom til. Det ble økt fokus på hygiene og et ønske om lettstelte glatte overflater. Dekormalingen gikk fra å være ornamental til å sette flatenes farger opp mot hverandre (Bibow 1958). Forsøk på å avhjelpe bolignød i byene gav tilvekst av nye leilighetskomplekser som skulle males enkelt, raskt og billig. Vedlikehold i eldre bygårder ble ofte overlatt leietagerne, som gjerne malte selv. Tapet av

enkel standard ble en populær erstatning for maling (Maleren 1939b).

Å fremskaffe velfungerende maling til overkommelig pris var viktig for bevaring av bygningsmassen og derfor for hele samfunnsøkonomien. Linoljemangel og høye priser krevde bedre utnyttelse av linoljen som ble foredlet og videreutviklet. Malingsindustriens laboratorier eksperimenterte med å forene linolje, andre oljer og syntetiske bindemiddel (Johansson 2004). Tungoljen forble viktig i produksjonen av ferdigmaling og lakk.

Ferdigprodusert maling ble solgt i faste fargekolleksjoner eller som grunnfarger malerne justerte selv (Bing 2011). Malerne fikk langt flere materialer å forholde seg til, og det ble stadig viktigere med materialkunnskap (Bibow 1958). Parallelt med nye materialer ble det også utviklet nye metoder for påføring av maling, som sprøyteteknikker og strukturmaling.

Bindemidler til interiørmalinger utviklet i mellomkrigstiden

I det følgende presenteres den internasjonale utviklingen av syntetiske bindemidler i mellomkrigstiden, sammen med eksempler på hvordan bindemidlene ble tatt i bruk i interiørmalinger i Norge.

Nitrocelluloselakk

Etter første verdenskrig ble lakkering og polering av møbler og trevare med skjellakk avløst av nitrocelluloselakk. Nitrocelluloselakk ble laget av restlagre fra første verdenskrig; av biprodukter fra produksjonen av «skytebomull» til dynamitt. Lakken lages ved at cellulose fra bomull dehydreres og reagerer med salpetersyre. Esteren som da dannes blir løst i organiske løsemidler. Nitrocelluloselakk skiller seg fra tradisjonell olje- og harpiksbasert maling og lakk, i det at den tørker ved fordamping av løsemiddelet og forblir løselig i dette (Standeven 2011). For fargeindustrien åpnet celluloselakken muligheten til mer brilliante og lysekte farger (Brenna 1989).

Celluloselakkene var i utgangspunktet svært tyntflytende, og fungerte bedre til spray enn pensel. I Norge var Alf Bjerckes fabrikker tidlig ute, med «Golac» til sprøytemaling i 1926 (Brenna 1989). Litt etter kom «Golac Lynmaling» til penselstrykning på markedet (Fig. 8). Malingen var blank som oljemaling, tålte såpe og lut og var slitesterk. I følge «Lynmaling»-brosjyrene var tiltenkte bruksområder i interiører først og fremst

Figur 8. Cellulosebasert «Golac lynmaling». Udatert. Eier/foto: Norsk Teknisk Museum.

gulver og trapper, men også «småmaling» som vindusposter og møbler. Dårlige pensleegenskaper gav imidlertid celluloselakkmalingene en kort popularitet, skriver Standeven (2011), og mot slutten av 1920-årene var de i stor grad erstattet av alternative hurtigtørkende produkter som inneholdt tungolje eller kunstharpikser, eksempelvis kunstkopal[6] eller fenolharpiks (se nedenfor). Til sprøytemaling av møbler o.l. fortsatte bruken av nitrocelluloselakk.

Oljelakkfarger basert på kunstharpiks

Fenolharpiks

Særlig i Tyskland og USA hadde kjemikere eksperimentert med å fremstille kunstharpikser som kunne avløse naturlige harpikser og danne bedre, reproduserbare lakker i oppløsning med tungolje og linolje (Bjercke 1955).

Reaksjon mellom formaldehyd og fenol dannet fenolharpiks (Bakelitt). Til bruk i maling og lakk ble fenolharpiksene løst i olje, ikke i sprit som de tidligste variantene. Fenolharpiksene hadde god farge og

holdbarhet, var vann- og kjemikalieresistente og tørket raskt. De konkurrerte med nitrocelluloselakkene om markedet for hurtigtørkende produkter, men de lignet mer på tradisjonell maling i konsistens og var derfor bedre egnet til penselpåføring. Fenolharpiksene dannet grunnlaget for mange 4-timers emaljemalinger på 30-tallet, også som matt og blank interiørmaling for vegger og listverk (Standeven 2011). Samtidig med fenolharpiksene kom også maleinatharpiksene på markedet.[7] Maleinatharpiksene var særlig godt egnet til lyse farger og interiørmaling. I norsk malingshistorie ble inntreden av oljeløselig fenolharpiks datert til 1928 og maleinatharpiks til 1933 (Bibow 1958).

Figur 9. Reklamefigur for tungoljebasert «Oxanoljemaling». Inneholdt den også kunstharpiks? Udatert. Eier/foto: Jotun Informasjonssenter .

De modifiserte fenolene fungerte godt sammen med tungolje (Standeven 2011) som ble mye brukt i Norge. Selv om tilsetning av de nye harpiksene så langt ikke er funnet uttalt for navngitte malinger, er det sannsynlig at de ble brukt i blanding med tungolje i Norge, for eksempel i «Oxanoljemaling» (Fig. 9).
På 1930-tallet inneholdt trolig de fleste hurtigtørkende lakk- og malingsprodukter i USA og Storbritannia oljeløselig fenol- eller maleinatharpiks, og den gamle oljelakkfabrikasjonen basert på naturlige harpikser forsvant gradvis. Bruken av fenolharpikser minsket imidlertid i løpet av andre verdenskrig til fordel for alkydharpikser, og brukes ikke lenger til interiørmaling (Standeven 2011).

Alkydharpiks (alkydolje)

Fra 1929 kom kunstharpikser av typen alkyd på markedet. Alkydharpiks, eller alkydolje, består av en lang hydrokarbonkjede med to dobbeltbindinger, noen syregrupper og en aromatisk ring. De ligner derfor både på olje og harpiks. Alkyd i hus- og interiørmaling var vanligvis en forbindelse av ftalsyre og glyserol. Til produksjon av alkyd til interiørmaling brukte man såkalt fete, oksiderende, tørkende harpikser, tilpasset for pensling. De tidligste alkydbaserte malingene var vanskelige å penselstryke, gav rennemerker og tørket for raskt. Før andre verdenskrig ble de laget i en fusjonsprosess som gav et ustabilt og mørkt produkt. Linolje ble brukt til produksjonen av alkyd til interiørmaling, men fordi linoljen ble misfarget ved aldring og var uegnet til produksjon av lysere farger, ble den byttet ut først og fremst med soyaolje etter andre verdenskrig. Fra slutten av 1930-tallet ble både løsemiddelbaserte alkyder og alkyder i emulsjoner brukt i husmaling. Emulsjonene ble brukt i kontorbygg, hoteller, skoler og sykehus; i bygninger som krevde

Figur 10. «Bengalac», en alkydbasert emaljemaling. Udatert. Eier/foto: Norsk Teknisk Museum.

luktfri, holdbar og raskt tørkende maling (Standeven 2011). I Norge produserte Alf Bjerckes fabrikk den alkydbaserte emaljelakken «Bengalac» fra 1931 (Fig. 10) (Bjercke 1955).

Klorkautchuk

Bindemidlet klorkautchuk er en semipolymer laget av klorert naturgummi. Klorkautchukmaling var vann- og kjemikaliebestandig og ble viktig på 1930-tallet i industrien. I Norge ble for eksempel malingen «Vulkasit», beskyttende mot korrosjon, produsert ved Alf Bjerckes fabrikk (Bjercke 1955). Standeven skriver at naturgummi også ble brukt i olje- og vannbasert husmaling på 1930 og 1940-tallet (Standeven 2011).

Metylcellulose

Semicelluloseproduktet metylcellulose er bindemidlet i vannløselig celluloselim. Metylcellulose er datert i Norge til 1935 (Bibow 1958). Annonser for «Glutolin» dukket opp i Maleren fra 1936 (se Fig. 13). Metylcellulose kom fra Tyskland som tørrstoff, hovedsakelig fremstilt av gran. I artikler i Maleren ble den beskrevet som en revolusjonernede nyhet for malerfarget, men dyr. Limet verken råtnet eller endret farge, noe som var etterspurte egenskaper. Bruken var mangfoldig; til isolering og tapetsering, til hvitting av tak og til emulsjonsfarger, sparkelfarger og plastisk maling (Maleren 1935b; Maleren 1936).

Standoljer

I løpet av 1920- og 30-tallet hadde man lært å varme opp rå linolje til ulike temperaturer uten lufttilførsel. Slik fikk man en lang rekke standoljer med ulike egenskaper som økt glans, god utflytning samt økt vann- og kjemikaliebestandighet. Men standoljene hadde noen ulemper: De tørket langsommere, trakk dårligere inn i underlaget og var vanskeligere å stryke ut. Fra begynnelsen av 1930-tallet utviklet man i Tyskland de såkalte «blåste» standoljer, uten de nevnte ulempene. Derfra kom også klorbehandlet linolje, kalt «faktorolje», med vann- og kjemikalieresistens. Begge typer ble produsert i Sverige (Johansson 2004). Norskprodusert faktorolje til bruk i strukturmaling ble presentert i Maleren i 1935. I samme artikkel ble det informert om at faktoroljen da allerede fantes i blank og matt maling for innvendig bruk (Maleren 1935a).

Alternative oljer

Hvilke alternativer til linolje var aktuelle? Også tungoljen var tidvis kostbar og vanskelig tilgjengelig. I USA hadde man startet opp utvikling av alternative oljer til linolje og tungolje, og denne utviklingen var «i full blomst» på 1930-talet.

Som en erstatning for tungolje ble dehydrert castorolje viktig i USA og Tyskland mot slutten av 1930-tallet. Oljen var værbestandig og gulnet lite. I Norge (Alf Bjerckes fabrikker) ble castoroljen særlig viktig for tekniske lakker (Bjercke 1955). Oiticicaolje fra Brasil ble brukt til erstatning for tungolje fra midten av 1930-tallet, også i Norge (Bjerke 1955; Standeven 2011). Den var imidlertid ikke like slitesterk som tungolje (Johansson 2004). Soyaolje er i utgangspunktet halvtørkende, men ble fra begynnelsen av 1930-tallet prosessert til en tørkende olje. På 1930-tallet ble den brukt i stor utstrekning i amerikansk malingsindustri, ikke alene, men i blanding med linolje. Soyaoljen var særlig anvendelig for de lysere fargene. I 1936 ble soyaolje importert også til Tyskland for malingsproduksjon (Standeven 2011), og ble etter hvert brukt i Norge. Etter andre verdenskrig ble den viktig til fremstilling av alkyder (Bibow 1958, Bjercke 1955).

Behov for mer materialkunnskap

Kjennskap til riktig bruk av materialene hadde ikke vært noen større utfordring med det tradisjonelle materialutvalget. Men med et vell av nye produkter på markedet ble det nødvendig med mer kunnskap. På Malerstevnet i Danmark i 1941 fortalte Ingeniør Aabye om den danske forsøksstasjonen som ble opprettet i 1917 på Teknologisk institutt. Mye på grunn av de materialvanskeligheter som første verdenskrig medførte, skulle forsøksstasjonen føre kontroll med de materialer som ble anvendt i malerfaget. Stasjonen startet med å teste de mange mer eller mindre ubrukelige linolje- og terpentinerstatningene som var i bruk (Maleren 1942e). Etter hvert utarbeidet stasjonen normer for vanlige malervarer (Maleren 1939c).

I Norge ønsket man seg også en forsøksstasjon. Nye patentmalinger var kommet på markedet, uten at resultatet svarte til anbefalingene. Fra 1939/40 tok Statens teknologiske institutt i Oslo ansvar for å foreta undersøkelser og prøvninger av farger og materialer (Maleren 1939a), og i 1949 ble det opprettet en egen avdeling for malematerialer (Bibow 1958).

Andre verdenskrig 1939-1945

Både i Norge og nabolandene ble det meldt om mangel på linolje, om hamstring og høye priser. Det var også mangel på tungolje, og etter hvert ble varene rasjonert. Som under første verdenskrig, rettet malingsproduksjonen i USA og Storbritannia seg nå

mot krigsformål. Det lille av interiørmaling som ble produsert der, ble laget av naturlig forekommende oljer og harpiks. Det var ikke før på slutten av 1940-tallet at de oljemodifiserte alkydene kom tilbake (Standeven 2011).

Krigsutbruddet i 1940 i Norge satte en stopper for tilførsel av de fleste råstoffer til de norske fabrikkene. Malingsproduksjonen måtte legges om og ble etter hvert redusert, selv om det ble arbeidet med å skape erstatninger for stoffene som ikke kunne importeres (Bjercke 1955; Bryn 1997).

Forskrifter om bruk av linolje og linoljemaling under andre verdenskrig

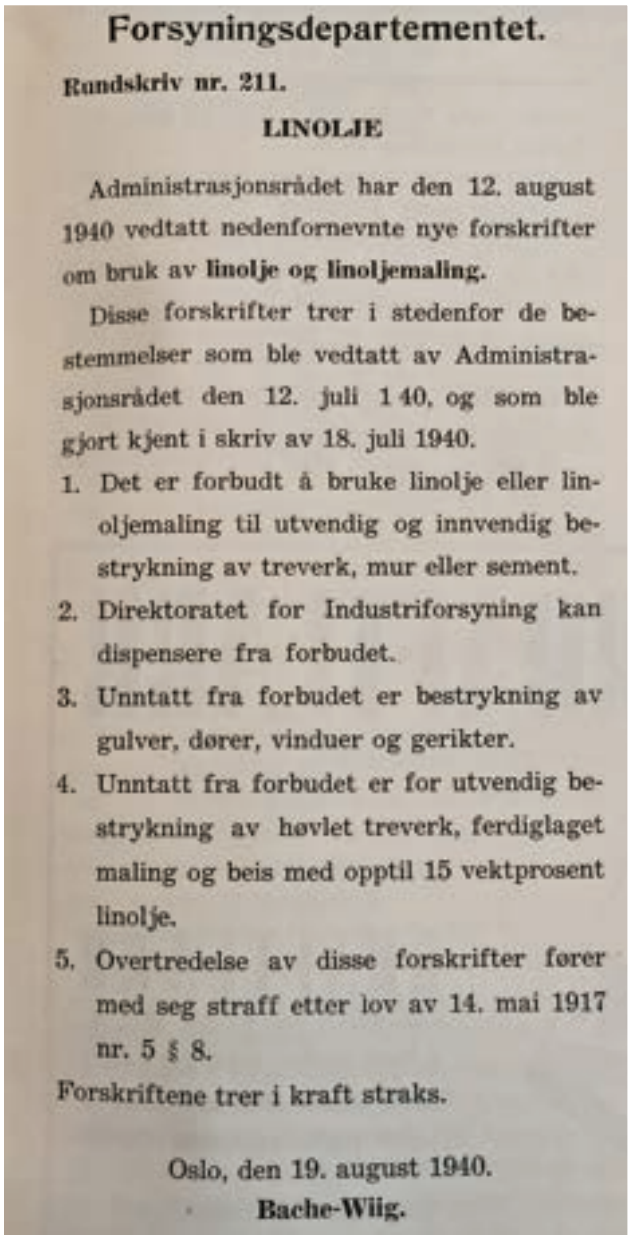
Okkupasjonsmakten tok det meste av tilgjengelig linolje til bruk på sine anlegg. I august 1940 kom en ny forskrift for bruk av linolje og linoljemaling (Fig. 11). I utgangspunktet var all bruk av linolje nå forbudt, med unntak av til maling av gulv, dører, vinduer og gerikter. Til utvendig, høvlet treverk kunne maling og beis med opptil 15 vektprosent linolje benyttes (Maleren 1940a).

Bindemidler brukt under andre verdenskrig i Norge og Norden

Standardisert oljeerstatning

I Norge ble det i 1940 påbudt at malingfabrikkene skulle produsere malerolje som inneholdt 50% linolje og 50% sildeolje. Maling skulle inneholde kun 15% av denne maleroljen, og bare brukes til utvalgte formål (Maleren 1940c). Et linoljesurrogat etter denne oppskriften var maleroljen «A» fra Lilleborg fabrikker, Norges viktigste linoljeprodusent. Malerolje «A» erstattet den veletablerte kokte linoljen «Libolin» (Fig. 12) og var sagt å ha lignende stryke- og tørre-egenskaper, men ville ikke bli like hard (Maleren 1940b).

I 1941 informerte Ingeniør Aabye ved den danske forsøksstasjonen om undersøkelser av erstatninger for kokt linolje. I løpet av dette året ble 300 forskjellige erstatninger testet, men kun 23 ble godkjent. Stasjonen forsøkte å utvikle en standardisert oppskrift for erstatningsolje (Maleren 1942e). Denne oljeerstatningen ble også beskrevet av den danske fabrikken Sadolin, som en enhetsvare kalt «M.F.» med 15% linolje, til fastsatt pris. Oppskriften skulle stilles til rådighet for enhver fabrikk som hadde tillatelse til fremstilling (Maleren 1941f). I Sverige var det fire godkjente erstatningsoljer med ulikt prosentinnhold av linolje: «Linylin», «Faktor», «Faktor grundolje» og «Tidol» (Maleren 1941a). De blåste standoljene ble



Forsyningsdepartementet.

Rundskriv nr. 211.

LINOLJE

Administrasjonsrådet har den 12. august 1940 vedtatt nedenfornevnte nye forskrifter om bruk av **linolje og linoljemaling.**

Disse forskrifter trer i stedenfor de bestemmelser som ble vedtatt av Administrasjonsrådet den 12. juli 1 40, og som ble gjort kjent i skriv av 18. juli 1940.

1. Det er forbudt å bruke linolje eller linoljemaling til utvendig og innvendig bestrykning av treverk, mur eller sement.
2. Direktoratet for Industriforsyning kan dispensere fra forbudet.
3. Unntatt fra forbudet er bestrykning av gulver, dører, vinduer og gerikter.
4. Unntatt fra forbudet er for utvendig bestrykning av høvlet treverk, ferdiglaget maling og beis med opptil 15 vektprosent linolje.
5. Overtredelse av disse forskrifter fører med seg straff etter lov av 14. mai 1917 nr. 5 § 8.

Forskriftene trer i kraft straks.

Oslo, den 19. august 1940.

Bache-Wiig.

Figur 11. Forskrift om bruk av linolje. Maleren 1940. Foto: Wedvik.

viktige erstatninger i Sverige under andre verdenskrig (Johansson 2004).

Animalske oljer fra havet

I artikkelen I dagens løp. Ny olje? (Maleren 1940d) ble det referert til to nye, foredlede fiske- og sjødyroljer til bruk som maleroljer, produsert ved oljeraffinerier i Norge. Begge oljene skulle gi mye bedre egenskaper i maling enn malerolje «A». Malingsfabrikanten

Jotun produserte malingen «Gardol» av sjødyrolje, og «SW-olje», som var et produkt for blanding med tørrpigmenter som bestod av sildeolje, avfallstran og udestillert svartlut fra celluloseindustrien (Bryn 1997).

I 1941 hadde Sadolin prosessert frem en tran til maling som ikke luktet og som tørket godt; «på den måte man har bruk for i farvefabrikasjon: hurtig, hårdt, klebefritt og ikke reversibelt» (Maleren 1941g: 163). Dette skulle være en klar forbedring fra tidligere lignende produkter som luktet heslig, tørket svært sakte og forble et klebende, mykt lag som myknet i solen og som løstes opp igjen av nytt strøk tran. Også i Sverige brukte man som følge av råvaremangelen i noen grad fisk- og sildeolje til alkydproduksjon. Oljen ble importert til Sverige fra Norge og USA (Johanssen 2004).

Figur 12. Lilleborg fabrikker reklamerte ikke for erstatningsproduktet malerolje «A». Derimot ble det reklamert aktivt for den fremtidige linoljen «Libolin». Maleren 1943. Foto: Wedvik.

Bjercke (1955: 55) skriver at i linoljemøllene ble linoljen først blandet halvt om halvt med fiskeolje på myndighetens befaling for å drøye linoljen. Men etter hvert ble det bare brukt sjødyrolje, også i maling til innendørs bruk, «og det var ikke så morsomt».

Tallolje

Standeven (2011) skriver at tallolje er en halvtørkende olje som ble tatt i bruk som alternativ oljeressurs under andre verdenskrig. Den ble destillert fra svartlut, et avfallsprodukt fra celluloseindustrien. Talloljen var ikke rasjonert i Norge under andre verdenskrig og ble brukt til produksjon av gulvlakk og til interiørmalingen «Estrol» (Bryn 1997). Den ble også produsert og brukt som oljeerstatning i Sverige (Johanssen 2004). Bibow (1958) skriver at talloljealkyd ble et viktig råstoff i Norge fra 1944

.

Tjære

Tjæreoljeferniss ble utvunnet av harpikser som var biprodukter fra celluloseindustrien. De finske malerne hevdet at den tørket raskt, «fortare än norrmännens sildolja» (Maleren 1941e: 159). Tjæreoljefernissen gav en halvmatt overflate og var vannfast, men tålte ikke sprit (etanol) eller bensin. Tjærebeis ble også annonsert for av Grorud Kemiske Fabrik i Oslo: «For noen år siden tenkte ingen på at vår skog skulle skaffe råstoffer til impregnerende bestrykningsmidler og til dekorasjonsfarver. Nu skaffer våre retort- og destillasjonsanlegg i skogene råstoffene både til Tjærebeisen og Interiørbeisen» (Maleren 1943).

Metylcelluloselim

I begynnelsen av andre verdenskrig drøyde man den oljen som fantes. Da også terpentin ble utilgjengelig, ble man tvunget til å klare seg med oljefri maling, som for eksempel kaldlimmaling. Mange av kaldlimmalingene ble omtalt som veldig gode, om enn ikke fullt vaskbare (Maleren 1942d). Til kaldlimmaling bredte bruken av metylcellulose seg. Metylcelluloselimet «Glutolin» ble produsert i Tyskland og ble, som et av få tilgjengelige produkter, hyppig annonsert for i Maleren helt til 1944 (Fig. 13).

Oljefri komposisjons- og sparkelfarger

Oljefri malingsprodukter var ikke rasjonert og det ble derfor startet opp produksjon av slike ved flere fabrikker i Norden. Sparkelfargene var blitt viktige på 1930-tallet. Begrepene «oljefri komposisjonsfarge» og «oljefri sparkelfarge» ble brukt om produkter som ikke inneholdt tradisjonell linolje, men som ellers kunne inneholde forskjellige tilgjengelige bindemidler samt emulgator. Johansson skriver (2004), som eksempel, at det i Sverige fra 1930-tallet ble tatt i bruk en ny type emulsjonsfarge; en kombinasjon av kasein og syntetiske bindemidler, først og fremst alkydharpikser, som erstatning for linoljefarge. I 1942 beskrives syntetisk emulsjonsmaling til utvendig bruk som «fullgod, men kostbar» (Maleren 1942d). Men det var grunn til å være varsom. I forbindelse med kontroll av emulsjoner og linoljeerstatninger ved den danske forsøksstasjonen under andre verdenskrig,

Figur 13. Annonse for celluloselimet «Glutolin». Maleren 1944. Foto: Wedvik.

viste såkalte «syntetiske fernisser» seg å inneholde alt fra mineralolje til harpiksoppløsning i sprit og celluloselakker (Maleren 1942e).

Nitrocelluloselakk

Mangelen på bomull gjorde at man under den andre verdenskrigen tok i bruk cellulose fra trær til fremstilling av nitrocelluloselakk. Den norskproduserte celluloselakken «Golac» skal ha inneholdt erstatningsprodukter for bomull til lenge etter andre verdenskrig (Brenna 1989). I Norge ble celluloselakk brukt så lenge det var tilgjengelig, men en artikkel fra 1943 informerte om forbud mot å fremstille og forhandle celluloselakk uten tillatelse fra Industriforsyningsdirektoratet (Maleren 1943). Hos Beckers i Sverige ble det i løpet av andre verdenskrig utviklet en cellulosebasert lakkmaling, «Ferbolacken», med tilsetning av hjemmeprodusert alkyd (Johansson 2004).

Status i Norge i 1942

Midtveis i 1942 var dette situasjonen for tilgang på malematerialer i Norge (Maleren 1942f):

- Terpentin var erstattet av sulfatterpentin fra celluloseindustrien
- Det var trolig ikke mulig å få tak i oljemaling til bruk i hus uten anvisning, bare til dører og vinduer utvendig
- Nytt og høvlet utvendig panel kunne i noen til feller få tranmaling
- Malematerialer til innvendige arbeider ble inn vilget kun med attest fra helserådet; til sykehus, næringsmiddelbedrifter og skoler
- Gulvmaling og lakk var det mest problematiske å få tak i
- Oljeholdige komposisjonsmalinger måtte søkes om
- Oljefri komposisjons- og sparkelfarge hadde vist seg overraskende gode
- Av limstoff fantes kun noe celluloselim

Gode råd om maling i krigsperioden 1939-1945

Under andre verdenskrig gjengav Maleren mange råd om hvordan man skulle forholde seg til materialmangelen. Disse kom særlig fra Danmark og fagmiljøet rundt den danske forsøksstasjonen. Nedenfor er sammendrag av råd som antas å ha vært relevante også for norske forhold (Maleren 1941b; Maleren 1942a; Maleren 1942b, Maleren 1942c).

Til limfarge i tak anbefaltes celluloselim som bindemiddel. Denne var god, men dyr. Limfarge til vegg lagdes nå også med stivelseslim, metylcelluloselim og kasein. Tidligere var limfarge til vegg oftest basert på animalsk lim, som også var det mest slitesterke og holdbare. Men før man kunne påføre slik limfarge måtte eldre limfarge på veggen isoleres med såpestrykning, og fordi det var krigsrasjonering også på såpe ble bruken av limfarge basert på animalsk lim problematisk. For limfarge basert på stivelse eller cellulose kunne det grunnes med tynn limløsning.

Emulsjonene kunne i visse tilfeller erstatte oljemalingen ved behandling av treverk, gulv og vegger. Til matte og vaskbare veggfarger kunne man bruke alkydbaserte emulsjoner; en stor del olje i emulsjonen ville gi en sterkere og mindre vannløselig maling. Forsøksstasjonens emulsjonsfarge bestod av lim, kaliumbikarbonat som gjorde malingen vannfast, kokt linolje samt vann. Det ble anbefalt å

kjøpe fabrikklagede emulsjoner og emulsjonsfarge fra fabrikkene for et mer stabilt produkt som ikke skilte seg. Trappevegger i murpuss malt med limfarge ville man tidligere malt over med oljefarge. Nå brukte man vaskbar emulsjonsfarge som lignet matt oljefarge, og som var godkjent av forsøksstasjonen.

På innvendig treverk ble tidligere enten alle strykninger utført med oljefarge, eller med sluttstrøk med emaljelakk eller -maling. Nå ble anbefalingen at det:

- Grunnes med emulsjon
- Sparkles med emulsjonssparkelfarge
- Strykning 1 à 2 ganger med emulsjonsfarge
- Ferdigstrykning med emulsjons-, lakk- eller emal jefarge

Anbefalingen i tidsskriftet Farve og Lak var for de innerste lagene lakkrevne farger fortynnet med «Fortynningsolje 959»: en fiskeolje som etter behandling var nærmest for en lakk å regne. Siste strykning var med en ferdig emaljemaling eller lakkfarge i deig fortynnet med glanslakk.

Foredlet sildeolje ble anbefalt til bruk både på vinduers innside og utside. Oljen måtte være av ordentlig fabrikat fra et anerkjent firma. Sildeoljen kunne brukes til å rive farger i; til fortynning som «grunnolje» eller fargeblandingsolje; og til å grunne nytt treverk inne. Produktet ble beskrevet som blankt og at det tørket litt langsommere enn linolje.

Lakkering og beising av treverk ble også anbefalt, da dette var materialbesparende. Beising ble tidligere stort sett utført av snekkerne, men nå ble malerne oftere bedt om å utføre dette. Man kunne lasere med oljeerstatning og pigment eller med vannbeis, et fargepulver løst i vann, som deretter ble lakkert med celluloselakk. Slik overflatebehandling kunne brukes i kjøkkener, entreer og loftsrom.

Mer tradisjonelle tilnærminger fant de norske malerne i anbefalinger fra Svensk Målaretidning. En grunnoppskrift på emulsjon bestod av vann, Borax, kokt linolje samt lakk av hard eller billigere myk harpiks. For grunnfarge tilsatte man hvitt pigment, deretter terpentin, terpentinerstatning eller linolje, alt etter behov. Til utvendig bruk tilsatte man kokt linolje, eller helst standolje (Maleren 1941c).

Restebøtta

Malingrester fra arbeidsplassene kunne samles og røres opp. Det var viktig å lagre oljefargerester og lakkfargerester hver for seg, og å skille lyse og mørke farger. Inntørkede malingrester kunne kokes med vann eller lut, eller løses med trikloretylen. Med tilsetning av dyrelim og tørrefarge fikk man emulsjonsfarge til grunning innvendig (Maleren 1942g).

Ubrukbare erstatninger

Det var de merkeligste materialer som ble sendt inn til den danske Forsøksstasjonen som erstatningsoljer. En prøve viste seg å inneholde 60% bensol og terpentinolje og 40% tran. En annen inneholdt 60% mineralolje. Farger ble revet i parafin. En terpentinerstatning bestod av kaustisk sodaløsning og en liten mengde bensol «for luktens skyld» (Maleren 1942e).

Det ble informert ut i malerfagmiljøet om forskjellen på vegetabilsk, animalsk og mineralsk olje. Animalske oljer, som tran og sildolje, kunne til en viss grad blandes med harpiks og linolje og bli tørrende oljer, men ville ikke tørke alene. Tilsetting av mineralske oljer i linoljen ville ødelegge tørkingen, og malingen ville ikke kunne males over (Maleren 1941d).

Etter andre verdenskrig

Komposisjonsmaling ble i mai 1945 beskrevet som «reddende engel nr. 1» under andre verdenskrig; at den var blitt brukt i utrolige mengder, men også at en del av arbeidet utført med «komp» burde vært ugjort. Særlig der malingen ble anvendt på tidligere oljemalt bunn (Maleren 1945).

Det tok lang tid før alle de tradisjonelle materialene var på plass igjen, blant annet på grunn av importrestriksjoner til Norge (Kvanvig 1990). Helt ut på 50-tallet kan man lese i annonsene i Maleren om materialer og produkter som er «kommet tilbake». Linoljen ser ut til å ha blitt frigitt i 1952 (Maling og lakk 1952).

Diskusjon

Materialmangelen under verdenskrigene førte til stor kreativitet ikke bare hos maling- og lakkfabrikantene, men også blant malere som ville ha noe å tilby sine oppdragsgivere. Gjennomgangen av litteratur og kilder viser at samtidig som de norske fabrikkene fulgte den internasjonale utviklingen med forskning og nyproduksjon, hadde mange malere for lite kunnskap om de nye produktene og bruken av disse. Det var

også mangelfull materialkontroll i Norge. Til sammen gav dette en del utfordringer og uheldige resultat.

Hva var forskjellen i materialutvalg og materialbruk fra fredstid til krigstid?

Emulsjonsmalingene ble særlig aktuelle når oljen måtte rasjoneres og oljeinnholdet i malingen reduseres. Spesielt for andre verdenskrig er utviklingen av oljefri emulsjonsmaling og sparkelfarge. Under begge krigene ble det anbefalt bruk av oljeholdige emulsjonsmalinger utendørs. Bruken av tran til maling var en ubrutt tradisjon langs norskekysten, men under krigene ble fisk- og sjødyroljer særlig aktuelle i Norge. Dette skiller seg fra USA og Storbritannia (Standeven 2011). Også bruken av biprodukter fra celluloseindustrien ble viktig i begge krigene.

Fabrikklagede ferdigprodukter ble anbefalt brukt under begge krigene, så lenge de var tilgjengelige. Ferdigproduktene ble sett på som dyre i bruk, men det kan se ut som de ble brukt i større grad i krigstid enn i fredstid av de etablerte malerne og at de ble brukt på måter de ikke var tiltenkt.

Men hvor mye ble det egentlig malt under krigene? De statlige direktivene gir en pekepinn på hva som kunne males og ikke, også i interiørene; om hvilke hus og hvor i et hus, og om hvilke produkter som var aktuelle å bruke. I Maleren ser man under begge krigene at fagmiljøet var opptatt av, og ble oppfordret til, å holde arbeidet i gang, men det ser ikke ut til å ha blitt malt mer enn det høyst nødvendige.

Hva var de viktigste forskjellene mellom materialutvalget under første og andre verdenskrig?

Den forrykende materialutviklingen i mellomkrigstiden gav et annerledes utgangspunkt under andre verdenskrig enn under første. Behovet for innsikt i nye arbeidsmetoder- og teknikker, og ikke minst materialkunnskap hos malerne, ble større. Mer spesialiserte produkter skulle velges ut til formålet, og brukes i riktig rekkefølge og blandingsforhold. Mens de fleste oppskriftene på emulsjonsmalinger som ble formidlet under første verdenskrig var basert på tradisjonelle materialer, inneholdt flere oppskrifter moderne produkter under andre verdenskrig. Særlig metylcellulosebasert lim ble ofte anbefalt i vannbaserte farger og emulsjoner.

Når linoljen forsvant under andre verdenskrig, ble det lagd standardiserte oljeerstatninger basert på animalske oljer. I Norge var oljene fra fisk og sjødyr viktige under begge krigene, men de var mer foredlet under andre verdenskrig. Mens tran, så vidt undertegnede kjenner til, ble brukt kun utvendig under første verdenskrig, ble den også brukt innvendig under andre verdenskrig (Bjercke 1955, Bryn 1997). Under første verdenskrig var hvalolje til maling omtalt i Maleren, men er ikke funnet omtalt eksplisitt under andre verdenskrig.

Mens anvendt erstatningsprodukt fra celluloseindustrien under første verdenskrig var løselig definert som sulfittlut (brunlut), ble det beskrevet bruk av fraksjonsprodukter fra sulfatlut (svartlut) under andre verdenskrig. Talloljen ble produsert ved at sulfatsåpe reageres med svovelsyre. Talloljen fraksjonertes deretter til talloljefettsyrer, harpiks (kolofonium) og tretjære (bek).[8]

Restlagre av ferdiglagde interiørmalinger ble brukt under begge krigene, men besto av langt flere typer bindemidler, og blandinger av disse, under andre verdenskrig. Bindemidler som hadde kommet til i mellomkrigstiden var nitrocellulose, fenolharpikser, de videreutviklede standoljene samt en rekke oljeerstatninger for linolje og tungolje, som dehydrert castorolje. Faktoroljen ble trolig brukt om den var tilgjengelig, slik det er beskrevet for Sverige (Johansson 2004). Alkyd ble produsert til «Bengalac» i Norge før andre verdenskrig, men det er tvilsomt at alkyd ble brukt i særlig utstrekning i interiører før krigen, da det var kostbart (Maling og lakk 1936). Under den andre verdenskrig stoppet alkydproduksjonen opp før man i 1944 begynte med talloljealkyd.

Konsekvenser for undersøkelser og bevaring

Tilstedeværelsen av erstatningsprodukter fra begge verdenskrigene kan forventes i eksteriør og interiør i historiske hus i Norge. I artiklene i Maleren ble det rapportert om erstatningsmalinger som ikke tørket, som flasset, manglet vedheft og ble som pulver på overflaten. En del av disse lagene har nok blitt fjernet når det kom bedre tider, mens andre kan fremdeles være på plass og bidra til malingsstrukturer med problemer. Noen malinger ble rapportert å være velfungerende maling, for eksempel ble det skrevet at oljefri emulsjonsmaling fra andre verdenskrig var overraskende god. Det er uvisst om slike lag også har holdt seg godt over tid.

	1900-1914	1914-1918	1918-1939	1939-1945	1945-1950
Linolje	X	(x)	X	(x)	(x)
Tungolje	X	(x)	X	(x)	(x)
Marine oljer (inkludert standolje, «lakk», alkyd)	(x)	(x)	(x)	X	X
Emulsjonsmaling	X	X	X	X	X
Emaljemaling	X	(x)	X	(x)	(x)
Animalsk lim	X	X	X	(x)	(x)
Islandsk mose	X	X	X	(x)	(x)
Kasein	X	X	X	X	X
Metylcellulose			X	X	X
Sulfitlut		X			
Naturlige harpikser	X	X	X	(x)	(x)
Nitrocelluloselakk			X	(x)	X
Fenolharpiks		X	X	(x)	(x)
Maleinatharpiks			X	(x)	(x)
Alkydharpiks			(x)	(x)	X
Klorkautchuk			X	(x)	(x)
Blåste standoljer			X	(x)	(x)
Faktorolje			X	(x)	(x)
Dehydrert castorolje			X	(x)	(x)
Soyaolje			(x)	(x)	(x)
Soyaoljealkyd					(x)
Tallolje				X	X
Tjæreprodukter fra sulfatlut				X	X
Talloljealkyd					X
Oljefri emulsjonsmalinger og sparkelfarge				X	X

Tabell 1. Tabellen viser antatt tilgjengelighet på maleprodukter for bruk i interiør i Norge i første halvdel av 1900-tallet.[1] X betyr tilgjengelig i perioden. (x) betyr lite utbredt, mindre tilgjengelig eller lite brukt. Tomt felt betyr at det enten ikke ble produsert, ikke var tilgjengelig ennå eller at bruken var opphørt.

1. Tabellen er veiledende og må leses med mange forbehold. Informasjonen som ligger til grunn, er omtaler i tekstform i artikkelens oppgitte kilder. Ingen kvantitative kilder er brukt. Oversikten skiller ikke mellom materialer som kun ble brukt i fabrikkproduksjon, og materialer som malerne kunne kjøpe for å blande maling selv.

For fargearkeologiske undersøkelser av interiører kan malingenes ulike egenskaper gjøre dem gjenkjennbare i malingsstratigrafien. Dette er kjennetegn som kan brukes som viktige ledetråder i tolkningen og dateringen av malingslag, og derved for forståelsen av historisk interiør og eksteriør. Kjennetegn som skiller seg fra malingsbruk i fredstid, og kan sies å være karakteristisk for perioden:

- fraværet av linoljemalte vegger
- bare ett oljelag på slitasjeutsatt treverk som dører, vinduer og gulv
- limfarge eller emulsjonsmalinger der man ellers ville forventet oljemaling, noen ganger med lakk som sluttstrøk
- grunderinger uten olje
- oljeholdig maling som ikke tørker og forblir myk
- ferdiglaget emaljemaling på elementer som skulle tåle rengjøring
- mer bruk av tjærebeis

Hvordan bør vi konservere og rekonstruere overflater med maling fra denne perioden? Husmalingenes respons på konserveringsmetoder er lite undersøkt, og det kan ikke gis faste retningslinjer for behandling (Standeven 2011). For bevaring og behandling av malingslagene er mangfoldet av bindemidler en utfordring. Bindemidlene har ulike egenskaper og vil respondere ulikt på behandling, men fra krigsårene kan man også forvente uforutsigbare variasjoner på grunn av justerte blandingsforhold og situasjonsbetingede materialblandinger.

Det er vanskelig å forutsi og krevende å finne ut hva en husmaling fra første halvdel av 1900-tallet består av, da syntetiske harpikser og naturlige produkter eksisterte side om side og krigene gjorde materialtilgangen ustabil og begrenset.

Oppsummering

Ved å sammenholde sekundærlitteratur om de nye malematerialenes opprinnelse, tilgjengelighet, bruksperiode og anbefalte bruksområder med informasjon fra det norske tidsskriftet Maleren, bidrar denne artikkelen til et mer utfyllende og nyansert bilde av malerfaget i første halvdel av 1900-tallet i Norge.

Den begrensede tilgangen på linolje under verdenskrigene forårsaket store endringer i malernes hverdag. Det førte til utvidet bruk av ferdigprodukter, til utvikling av nye malingsprodukter og til gjenoppliving av tradisjonelt brukte bindemidler i malingsproduksjon. Ferdigprodukter som emaljemaling fikk økt omsetning. Tran fikk en større rolle. Biprodukter fra moderne celluloseindustri kom i bruk. Tradisjonelle og moderne bindemidler ble blandet. Emulsjonsmalinger, både hjemmelagde malinger med erstatningsoljer og ferdigproduserte malinger, ble anbefalt, under andre verdenskrig også i oljefrie varianter. Celluloselakk og metylcellulose ble viktig under andre verdenskrig, så lenge de var tilgjengelige.

Etter hvert som materialene ble flere, mer prosesserte og spesialiserte, sank brukerkompetansen hos mange malere. Kombinasjonen av lavere kompetanse, varemangel og høye priser gjorde at produkter ble brukt på måter de ikke var tiltenkt, og med uønskede resultater. Malingenes kvaliteter, som påføringsegenskaper, tørkeevne og levetid, var svært varierende, også egnetheten av malingen som underlag for påfølgende strøk.

De mange ulike bindemidlene som kan være til stede i maling fra første halvdel av 1900-tallet, og muligheten for uegnet bruk, særlig under krigene, må tas i betraktning når man gjør undersøkelser og planlegger behandling av interiører og dekormalerier fra denne perioden.

Sluttnoter

1. Mer informasjon om tilgjengeligheten på bindemidler under første verdenskrig i Norge finnes i artikkelen ‘A Glimpse into the House and Decorative Paint Market in Norway During World War I (1914–1918)’ (Wedvik 2019).

2. Maleren er et norsk tidsskrift for hus- og dekorasjonsmaling, med malere og arkitekter som målgruppe. Bladet kom ut annenhver uke i perioden som omtales.

3. Referanser til Maleren vises i teksten med år og sidetall. Full referanse er oppgitt i referanselisten.

4. For å få oversikt over hvilke produkter som kommer og forsvinner, er maleprodukter publisert i produktannonser i Maleren registrert i en kronologisk tabell.

5. «Tran» er en samlebetegnelse for leveroljeprodukter fra fisk eller sjødyr.

6. «Ester gum»: naturlig harpiks (kolofonium) kjemisk modifisert (forestret) med glyserol, fra 1890-tallet. Oversatt med «kunstkopal» i Store norske leksikons nettside 20.02.2021.

7. Fremstilt ved oppvarming av kolofonium med maleinsyreanhydrid, og har deretter gjennomgått en forestring med glyserol.

8. «Tallolje», fra Wikipedia 20.02.2021.

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DELAMINATION OF THE PAINT STRUCTURE IN *PEINTURE*, DATED 1954 BY PIERRE SOULAGES

A STUDY ON SOAP FORMATION IN THE PAINT LAYER INTERFACE

Abstract

Peinture, 1954, by Pierre Soulages exhibits substantial delamination of the upper paint layers. Micro samples were collected from the different layers of the paint structure to provide further insights into the layer chemistry. The analysis revealed FTIR peaks indicative for high levels of zinc soaps at the interfaces on each side of a light-yellow zinc containing paint layer. Delamination is only occurring in areas beneath black paint features, suggesting that the black paint is playing a role. Analysis of the upper black paint revealed features characteristic for mobile oxidised free and acylglycerol bound fatty acids and diacids similar to those found in earlier studies of paintings with soft and dripping paint. The mobile fraction of the black paint is thought to be the source of fatty acids leading to zinc soap formation in the layer beneath. Samples were analysed with various microscopic and spectroscopic techniques. The results support the hypothesis that mobile fractions exuding into the layer structure enable the development of new compounds that weaken the adhesion of the layers by expansion and alteration of its physical properties, thus explaining the mechanisms resulting in the delamination. This investigation of the artwork emphasizes the importance of future preventive conservation strategies.

Introduction

To best preserve the art of Pierre Soulages (1919-) for the future there are two topics that conservation professionals will have to address: his soft black oil paint and the severe delamination of some of his paintings. A study was performed to investigate the possible relationship between these two symptoms, by examination and chemical analysis of microsamples from *Peinture*, 1954, in the Henie Onstad Art centre collection in Norway.

Peinture

The French artist Pierre Soulages has, throughout his career, investigated the juxtaposition of light and dark. He has used black to evoke both the presence of snow in early landscapes and light for the viewer of his artworks. In his later paintings, the reflection of light achieved a lively representation of the painted surface. In his earlier works, the texture of the black paint strokes is an important part of the experience (Figure 1). Delamination of the paint layers however, directly affects the visual effect of the surface.

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Keywords:
Pierre Soulages; paint delamination; soap formation; soft paint, SEM-EDX; py-TMAH-GC-MS; FTIR.

MOK

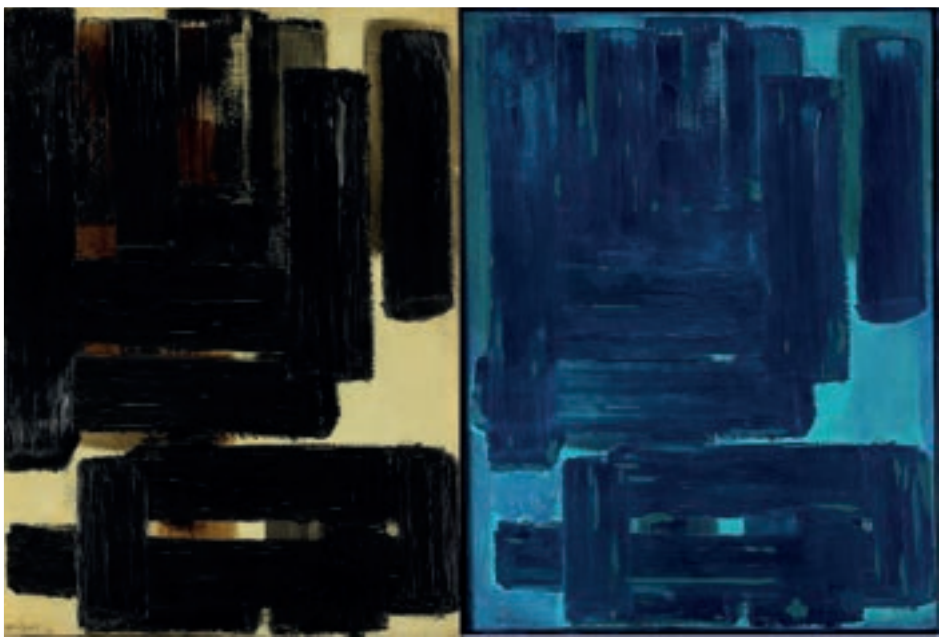

Figure 1. Pierre Soulages, *Peinture*. Oil on canvas, 81 x 60 cm. Henie Onstad Art Centre. In normal light (left) and luminescence from UV light (right). Photos: National Museum, Børre Høstland.

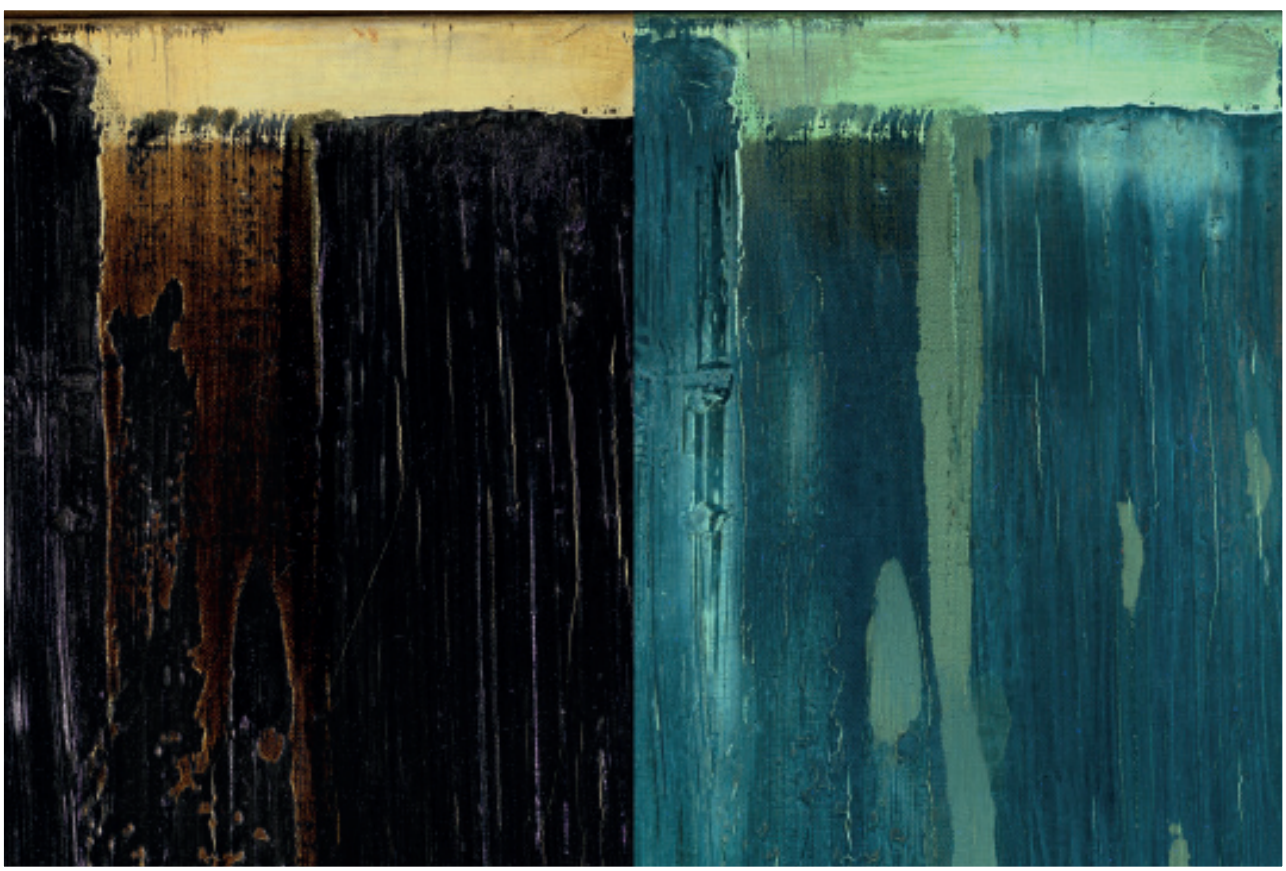

Figure 2. Detail from *Peinture*, in normal light (left) and showing the luminescence from UV light (right). Photos: National Museum, Børre Høstland.

Il y a de la lumière réfléchie par le noir, donc déjà modifiée, transformée. Si elle était réfléchie par du vert, du bleu ou par un miroir, ce ne serait pas la même. On voit de la lumière qui provient du tableau vers celui qui regarde : ça, c'est ce qui se passe dans ma peinture, c'est le côté optique […]. Si la lumière change de place, ce n'est plus la même peinture que l'on voit; et si le regardeur bouge, ce n'est pas tout à fait la même chose qu'il voit.

Pierre Soulages (Charliat 2019).

The light is reflected by the black, therefore it is already modified, transformed. If it was reflected by green, blue, or a mirror, it would not be the same. We see the light coming from the painting towards the viewer: that is what happens in my painting, it is the optical aspect [...]. If the light changes position, it is no longer the same painting that we see; and if the viewer moves, it's not quite the same thing they see.
(Translated to English by the first author).

The paint texture, the precision of the strokes and the shade or colour of the paint is fundamental to Soulages's artistic intent. Hence, when delamination of part of the structure interrupts our view, it changes our experience. The viewer can to some extent understand a change in the materials and look past it, particularly if they already know something about the work's age and the artist. Still there is a tipping point when the damage starts to change the visual impact excessively. In the worst cases, damage to the paint structure will dominate and stand in the way of the work being displayed in exhibitions. *Peinture* by Pierre Soulages shows this type of severe delamination.[1] Similar damage has been observed in other paintings by Soulages in both Norwegian and Finnish collections (Helou-de la Grandière et al. 2021). Soulages's paintings are not uniquely affected by this type of delamination; the same damage has been observed in works by other modern painters, for example Asger Jorn (1914-1973), Paul-Émile Borduas (1905-1960), Karel Appel (1921-2006), Hans Hofmann (1880-1966) and Georges Mathieu (1921-2012) among others (Challan-Belval 1991; Rogala et al. 2010; Ségogne, H. de 2012; Ségogne, H. de 2014; Bronken et al. 2019; O'Malley 2019). The findings from the various examinations of Peinture should therefore be a relevant supplement to earlier findings.

Soulages's material history

The material history of an artist is one of the sources in discussions of potential cause and effect of condition issues. The practical context for an artist's practice and work is an important part of understanding the artworks and their condition. Much information is already known about Soulages's materials (La Grandiere, de 2005; Hélou-de La Grandière et al. 2008 ; Hélou-de La Grandière 2019). It is well-known that the two companies Lucien Lefebvre-Foinet and Adam Montparnasse in Paris were Soulages's main suppliers (Hélou-de La Grandière et al. 2008; Corbeil et al. 2011). Observation of the technique used for *Peinture* identified several different glazes and transparent layers over and under the black paint strokes (Figure 1 and 2). This correlates with observations made on other paintings by Soulages at the time.

Since the painting studied here was painted in 1954, it was of interest to search for additional data about Pierre Soulages's technique at that time. One of the photographers who documented many of the artists congregating on the Left Bank in Paris in the 1950s was Denise Colomb. Her photographs are now in the Réunion des Musées Nationaux photographic archive (RMN in Paris). Colomb took a series of photographs of Pierre Soulages in his studio at 11 Rue Victor Schoelcher (Ragon 2004) in 1954 (Figure 3).

No logos or clear details are obvious in the photographs taken by Colomb. Still, two of the bottles have enough details to compare the information to known paint brand logos of the time. One glass bottle has an embossed logo on made in the glass that looks very similar to the logo of Lefranc Cie (1720-1965) seen in the mid-1900s (Figure 3, detail). The oval logo on the bottle to the far right, although not in full view or focus, is interpreted as the Talens logo (Figure 3, detail).

We know that Adam Montparnasse sold materials from Lefranc in addition to his own mixtures and blends (Andrieu et al. 2011). Soulages visited the shop regularly from 1946 (Andrieu et al. 2011). Talens' products might have been retailed by several shops in the Montparnasse area. As Soulages worked consistently in Paris at this time it is likely that the Talens brand was available in the local shops although it has not been possible to confirm this from other sources.

Figure 3. Pierre Soulages in his studio, 1954. Photo: Denise Colomb: Réunion des Musées Nationaux Agence Photographique (RMN). Underneath: Detail from figure 3 with interpreted historic logos. Illustration: Ida Bronken.

The worktable of Soulages shows both paint tins and tubes. Their logos are not visible, but the tube on the far right has raised lettering on the upper surface against the neck. The French paint brands mentioned in connection with Soulages - Lefranc, Bourgeois and Lefebvre-Foinet - have all raised lettering around the opening of historic tubes, so these brands are all candidates for matches with the tube on the right. Both the brand of Lefranc and Lefebvre-Foinet are mentioned in connection to other studies on soft paint, however, more work is needed on the material paint history of the 1950s and 1960s before the information from individual artists can be discussed with more certainty in connection with condition issues. The available documentation about Peinture supports the impression that Soulages made several additions to his paint at the time.

Painting technique and layer build-up

Peinture is among the early works of Soulages, and is painted with a juxtaposition of opaque, translucent and transparent layers (Figure 2). Unlike what we see in later works, the paint is not particularly pastose , and the surface is either unevenly varnished or given finishing touches of the coloured and transparent paint/glazes observed elsewhere in the painting structure (Figure 1 and 2). The support is canvas with a commercially applied ground. Judging from a cross-section, the ground is a two-layer application (Figure 8). The pre-primed canvas is most likely from the firm Lucien Lefebvre-Foinet, based on the shape and faint lettering of a stamp found on the reverse. Superimposed over the ground layer is a light-yellow paint, which functions as a background colour, covering the ground completely (Figure 1 and 8). From the luminescence seen from exposure to UV light, we can see more clearly that the background colour in normal light is painted over with a slightly deeper shade of yellow in areas towards the edges. The deeper shade of yellow has less luminescence in UV light and can be seen as darker areas (Figure 1 and 2). From purely visual observation, it is suspected that the background colour is leaner than both the ground and the black paint layer due to its matte appearance. The main motif has been built up with large black paint strokes, with tool marks corresponding to a broad and flat brush. The brush strokes are long, straight and defined – creating a subtle structural effect (Figure 4). Black and brown transparent glazes have been used by Soulages both over the background colour and above the black paint. Some of these transparent layers, coloured and luminescing orange in UV, were applied over drying cracks in the black paint (Figure 1 and 2). Under UV light there is a fluorescing or luminescing layer indicative of an uneven varnish (with or without pigmentation), but this has not been confirmed by analysis.

Condition

The coloured glazes over the cracks in the black paint have been added after the development of the cracks, possibly by Soulages himself. After the initial drying cracks in the black paint, new issues developed resulting in the present condition. Several straight and linear cracks penetrate the upper paint layers. In the severe cases, these layers curl up, mainly creating a separation between the yellow background paint and the upper ground layer (Figure 4 and 6). Because the ground is most likely from the

painting materials supplier Lucien Lefebvre-Foinet, it was likely that it was a lead white ground (La Grandiere, de 2005), which was later confirmed by analysis. This led to our working hypothesis that the delamination was a result of lead soaps from or on the upper layer of the ground (Helou-de la Grandiere 2008). From visual examination this is indeed where the adhesion is lost, but only in areas where the soft black paint is present (Figure 4). Hence, the idea that the soft black paint somehow contributed to the delamination issues in *Peinture.*

Figure 4. Detail of point of delamination in normal light. Photo: National Museum, Børre Høstland.

Delamination initiated by zinc soaps have been recently reported in a study on an Asger Jorn (1914-1973) painting in the same Norwegian collection (Bronken et al. 2019). Observations from a group of 20 paintings with soft and dripping paint from five Norwegian collections have shown that severe delamination occurs in combination with soft paint layers (Bronken, PhD thesis forthcoming). These delaminations have been observed in combination with zinc as well as lead containing layers. In paintings with soft paint over a lead white ground with delaminating paint layers, a glossy, transparent, web structure was observed (with the help of magnification) on the priming ground of the affected area. A similar phenomenon was also observed on *Peinture* (Figure 5).

Visible light and UV luminescence micrographs of the surface of the ground in a delaminated area are shown in Figure 5. The surface shows transparent, web-like elongated structures that have a blue luminescence under UV light (365 nm). These residual features suggest that when the ground and yellow background paint layers detached, a transparent residue was left on both sides of the delaminating layers. In some areas, the light yellow layer remains attached to the ground and the interface between the yellow and the black paint has detached. Figure 6 is a diagram illustrating the various layers in the delamination area. The illustration is based on both visual observation of the painting, and microscopic examination of cross sections made from embedded microsamples. The web-like structure on the interface with the ground is not the only sign of structural changes. On the interface between the yellow and the black paint layer a structural change is observable, with a more pronounced corrugated and ribbed texture. The Scanning Electron Microscopy (SEM) image at the top left corner of Figure 6 from the light yellow and black paint interface shows a corrugated structure with ridges and hollowed areas as if the delaminated area was rather soft and perhaps even fluid (Figure 6). Chemical investigation using Scanning Electron Microscopy Energy Dispersive X-ray spectroscopy (SEM-EDX) and Fourier Transform Infrared spectroscopy (FTIR) were used to identify the chemical compounds at the interface and their relationship to both over- and under-lying paint layers. For instrumental details see section *Experimental.* A previous study by Boon and Lister (2014) of another Pierre Soulages painting from 1960 reported that the binding media in the black paint and the exudates were rich in acidic oil derived fractions composed of free and glycerol-bound fatty acids and diacids. If similar mobile organic material was penetrating the lower layers of the *Peinture* it could provide a fatty acid source for a metal soap formation that would weaken the adhesion between the layers, leading to delamination. It was, therefore, important for comparative reasons, to take samples for FTIR, gas chromatography-mass spectrometry (GC-MS) and SEM-EDX to determine whether this was the case.

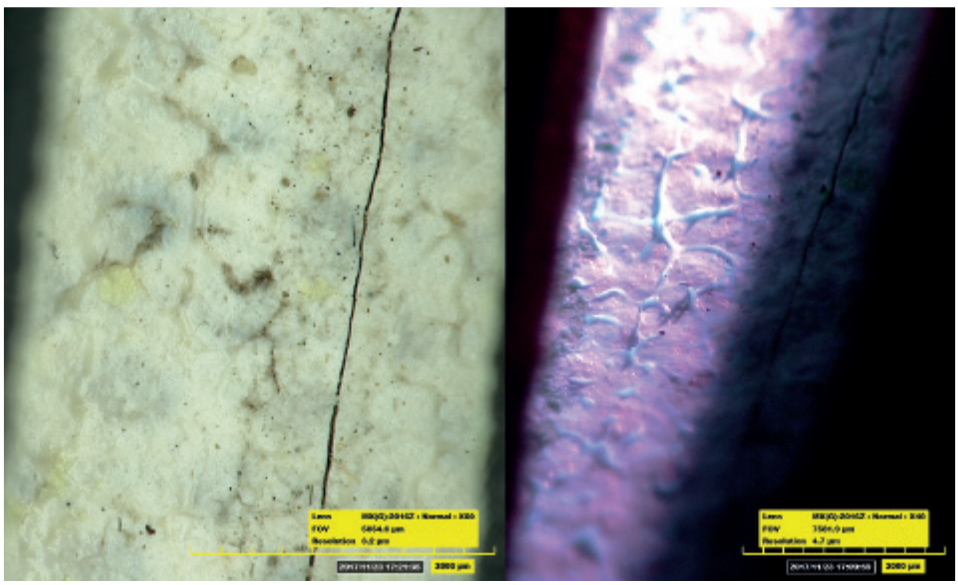

Figure 5. Area of delamination documented with Hirox microscope in normal light and the luminescence from hand-held raking UV light. A web of blue UV-luminescence residual elongated structures was visible on the delaminated interface. Photos: Jaap Boon.

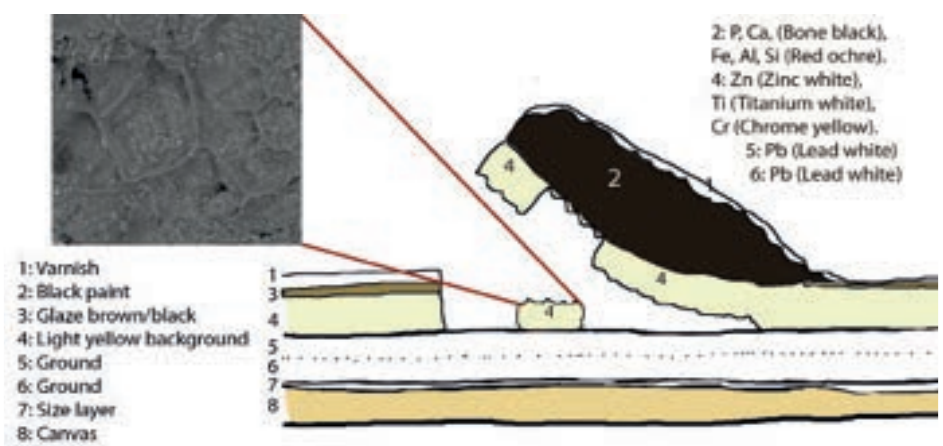

Figure 6. Illustration of the main layer structure. The layer thickness in the illustration is indicative. Both layer 1 and 3 vary greatly locally in both thickness and pigmentation. Illustration: Ida Bronken. The insert represents a SEM image of the delamination surface. SEM-EDX image: Calin Constantin Steindal.

Layer structure and SEM-EDX analysis

The painting's structure has three main elements: two applications of a white ground layer (layer 5 and 6), a light yellow background colour (layer 4), and black paint that makes up the main motif (layer 2) illustrated in Figure 6, 7, 8 and 9. Figure 6 is a schematic illustration showing the overall layer structure of the painting. Figure 7 shows a cross-section of the upper layers in a delaminating area, while Figures 8 and 9 show a cross-section from the edge of a main motif which does not exhibit delamination. Based on the chemical elements identified with SEM-EDX, the white ground layers are composed of lead white. The yellow background paint contains titanium, chromium, some lead and zinc, suggesting a mixture of zinc white, titanium white and chrome yellow. The presence of calcium and phosphorous in the black paint indicates bone black. The black paint also contains red ochre; red particles containing iron, silicon and aluminium were identified by SEM-EDX. The SEM-EDX results confirmed the visual observations, that both the background paint and the black paint are specially made mixtures with more than one pigment. The addition of yellow and red pigments indicates that Soulages made these paint mixes to obtain a warmer tone.

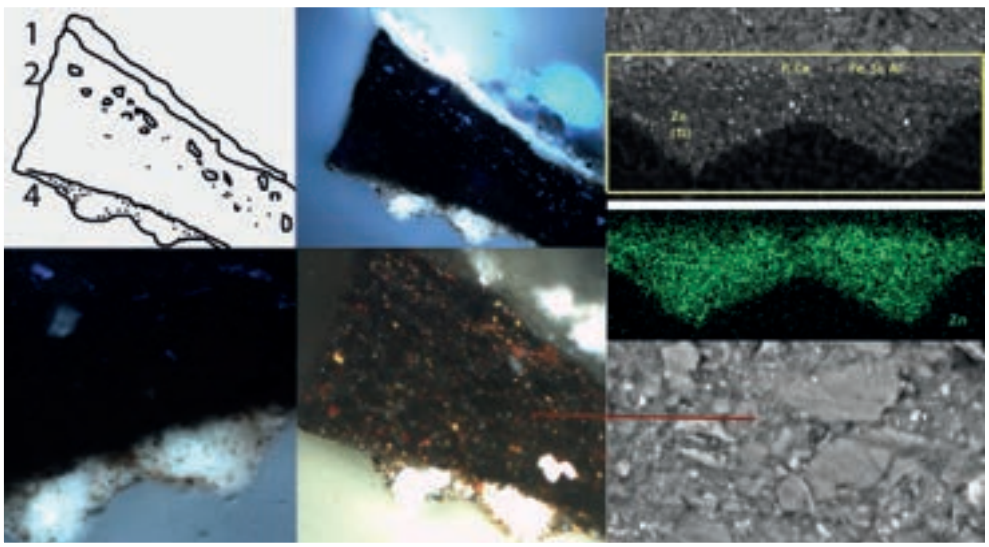

Figure 7. Illustration of a cross section from the upper layer of a delamination area, 1: Varnish/glaze, 2: Boneblack and red ochre, 4: Peaks of background colour/zinc soaps. SEM-EDX analysis of area in yellow square. Illustrations/ photo: Ida Bronken. SEM EDX: Calin Constantin Steindal.

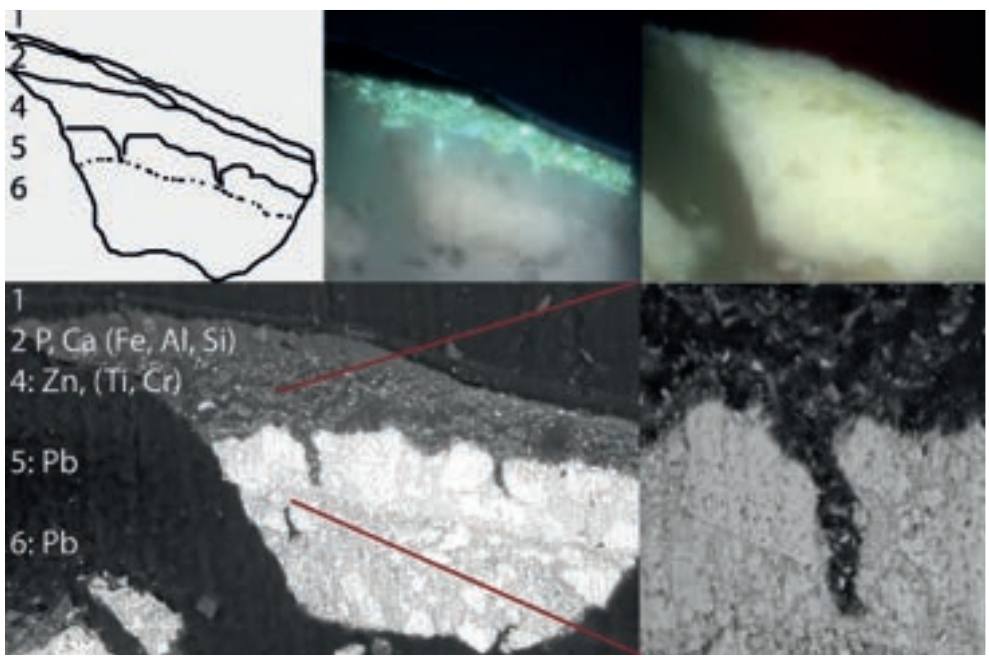

Figure 8. Cross section with the main layer structure from the edge of a black paint stroke. Clockwise from top left image: Layer illustration. Cross section in UV light. Cross section in normal light. Cross section in back-scatter. Detail from crack in the ground. Illustration and photos from microscope: Ida Bronken. SEM-EDX images: Calin Constantin Steindal.

The cross-section from the edge of a black stroke shows that the ground has deep cracks, filled by the yellow paint of the background (Figure 8 and 9). This sample was taken close to the tacking edge, so the pre-primed ground might have cracked due to the mechanical action of attaching the canvas to the stretcher prior to painting. Without cross sections or other investigation of the ground further into the motif, it is impossible to know what the general surface structure was like before the application of the background colour.

Figure 8 shows that the interface between the lead white ground and the background colour in the cross-section near the tacking margin appears intact without any signs of mobile lead or the development of new compounds like soap pockets at the interface (Figure 9). This suggests that no delamination between the lead white ground and background paint is occurring in this area.

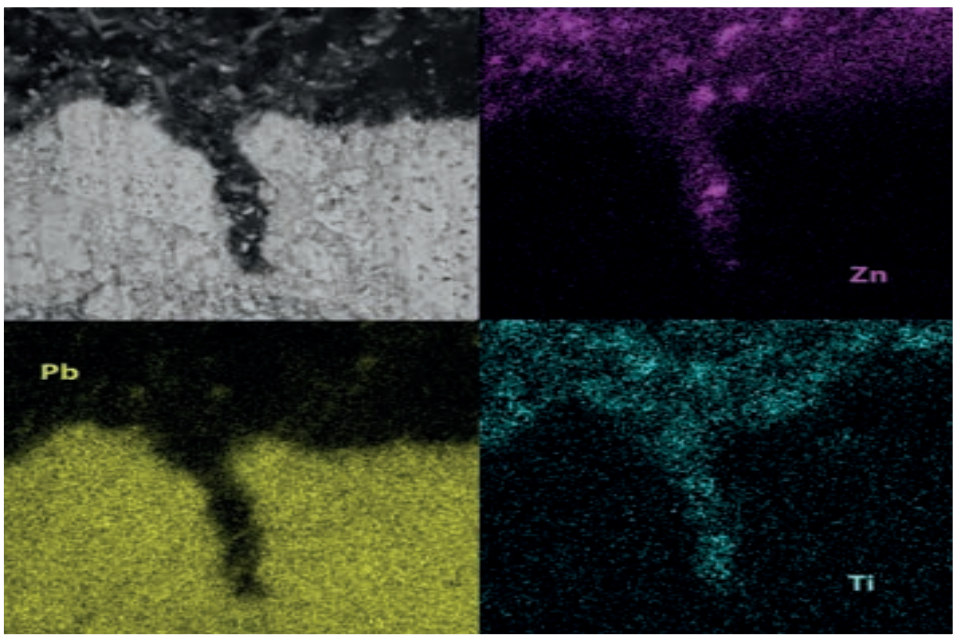

Figure 9. Map from the inter-phase between the ground and the background colour. SEM-EDX mapping: Calin Constantin Steindal.

Chemical observations

A microsample from the dark upper paint layer kept in-between glass slides showed a ring of transparent organic material that oozed out of the paint. This sticky material, or exudate, was investigated with gas-chromatography mass spectrometry using online pyrolysis methylation by tetramethylammonium hydroxide (py- TMAH GC-MS) to obtain methylated fatty acid methyl esters (van Keulen, 2014). Mass spectra were identified using the atlas for oil paint compounds developed by J. van den Berg (2002). Figure 10 shows the total ion current chromatogram of the exudate. The numbers correspond to identified compounds listed in Table 1.

The main peaks in the chromatogram are the C8 (nr 8) and C9 diacids (nr 9) with smaller relative amounts of the C7 (nr 6) and C10 (nr 11) diacids. The distribution of these diacids suggest some form of thermal pre-polymerisation of the oil binder (Mills and White, 1999; van den Berg, 2002). Less intense are the peaks for palmitic acid (nr 13) and stearic acid (nr 15). Other peaks of interest are methoxylated glycerols (nr 1, 2, 3) where the diglyceride precursors are more prominent (nr 1 and 3). Further compounds of interest are unsaturated hydroxyl-stearic acids (nr 16, 17), (9,) 10-epoxy-stearic acid (nr 18) and the (9,10)-dihydroxy-stearic acid (nr 19, 20). We infer that these types of fatty acids and diacids, either free or partially bound as esters to glycerol, are the main compounds that penetrated from the upper black paint into the lower paints layers. An FTIR spectrum of the sticky material (Figure 10) shows the main absorptions at 1735 and 1712 cm^{-1} indicative of glycerol esters and free acid groups (van der Weerd et al. 2005). Observations of soft paint in other case studies have shown that mobile fractions can move to other areas of the paint structure (Bronken, PhD thesis forthcoming). The hypothesis that the soft paint and its medium constituents is the root cause of the delamination is supported by an earlier published study on soap formation, which describes the relatively high fatty acid content of the soft paint (Bronken et al. 2019).

The level of hydrolysis in the black paint layer has not been determined analytically. It can be inferred that over time more fatty acids will become hydrolysed and free (Boon et al. 1997; van den Berg et al. 1999). It should therefore be a priority to monitor the condition, and development of the painting in this respect, in the future.

FTIR and GC-MS analysis of the black paint from *Peinture* point to a mobile phase of glycerol esters of saturated fatty acids and the various diacids observed. Similar compounds have been found in the binding medium of a Soulages painting from 1961 in the Sara Hilden Art museum in Tampere (Finland) where large delaminating areas have been

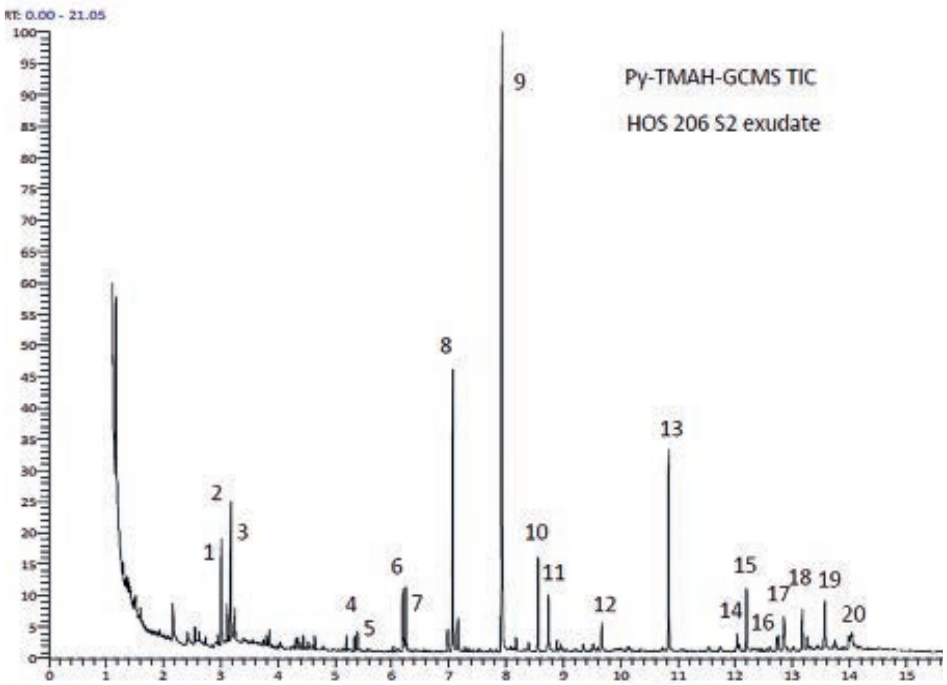

Figure 10. TIC (total ion current) profile generated from GC-MS data of the mobile transparent material exuding from the dark surface paint layer. GC-MS: Jaap Boon and Henk Van Keulen (RCE).

Nr.	Chemical compounds	Abbreviations
1	1,3-dimethoxy-2-propanol	GLY
2	1,2,3-trimethoxy-propane	GLY
3	2,3-dimethoxy-propanol	GLY
4	hexanedioic acid, dimethyl ester	C6 DF
5	decanoic acid, methyl ester	C10:0 F
6	heptanedioic acid, dimethyl ester	C7 DF
7	omega-oxo-octanoic acid, methyl ester	Oxo-C8 F
8	octanedioic acid, dimethyl ester	C8 DF
9	nonanedioic acid, dimethyl ester (azelaic acid)	C9 DF
10	tridecanoic acid, methyl ester (Internal Standard)	C13 F
11	decanedioic acid, dimethyl ester	C10 DF
12	alfa-methoxy decanedioic acid, dimethyl ester	OH-C10 DF
13	hexadecanoic acid, methyl ester (palmitic acid)	C16 F
14	octadecenoic acid, methyl ester (cis/trans)	C18:1 F
15	octadecanoic acid, methyl ester (stearic acid)	C18 F
16	11-methoxy-9-octadecenoic acid, methyl ester	OH-C18:1 F
17	10-methoxy-8-octadecenoic acid, methyl ester 9-methoxy-10-octadecenoic acid, methyl ester	OH-C18:1 F
18	9,10-epoxy-octadecanoic acid, methyl ester	Epoxy-C18 F
19	9,10-dimethoxy-octadecanoic acid, methyl ester	diOH-C18 F
20	9,10-dihydroxy-octadecanoic acid, methyl ester	diOH-C18 F

Table 1. Identified chemical compounds in Py-TMAH-GC-MS data of an exudate sampled from black paint of *Peinture* by Pierre Soulages.

Abbreviations:
F = fatty acid,
DF = diacid,
GLY = glyceride

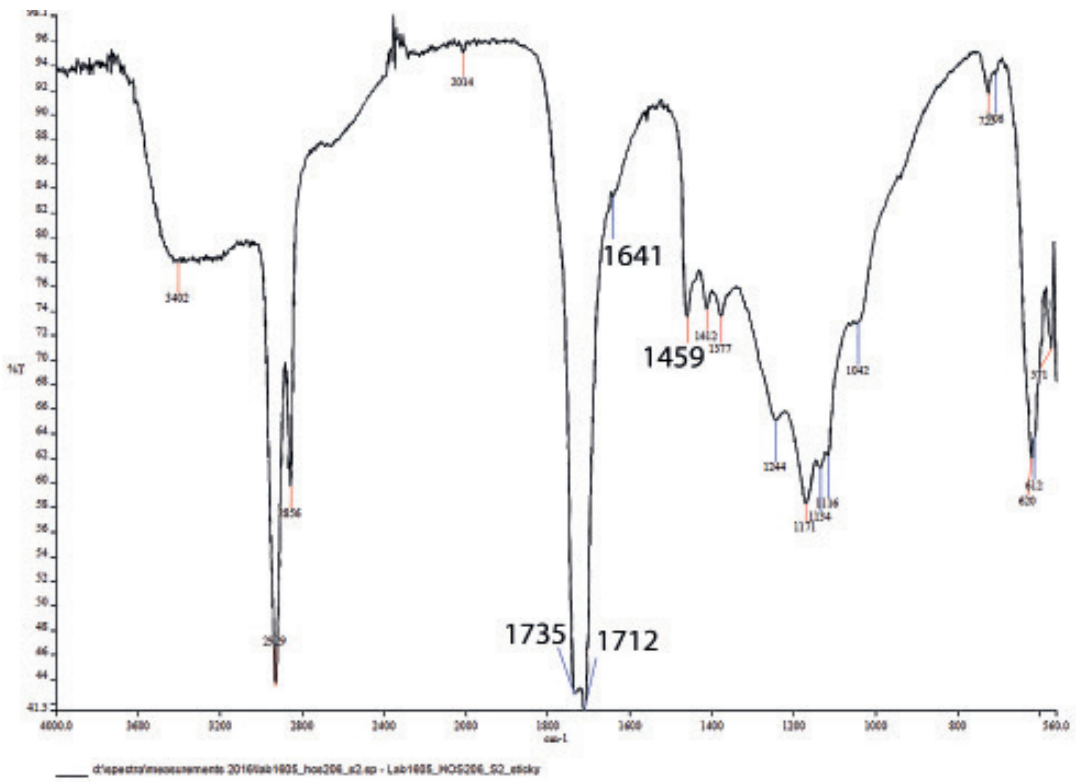

Figure 11. FTIR spectra of transparent exudate from the dark paint layer confirming the presence of glycerol-esters of fatty acids and diacids. Spectra: Karen Wyss, The Swiss Institute for Art Research Lab (SIK-ISEA).

investigated (Helou-de la Grandière et al. 2021) with MS and FTIR imaging. These compounds were also found to play a role in the softening of paints, and even in exudate formation in paintings by Riopelle (Bronken and Boon 2014; 2015) in which they turned into metal soaps linked to the delamination of the paints (Bronken PhD thesis, forthcoming). To investigate the hypothesis whether metal soap formation could play a role in the lifting of paint in *Peinture* various microsamples were obtained from within the delaminated area for study with attenuated total reflection FTIR (ATR-FTIR). Figure 12 shows the sampling locations in the paint layer diagram together with partial FTIR spectra of A, B, C and D. All spectra show CH vibrational features in the 2900 cm^{-1} range typical for long aliphatic chains of fatty acids (not shown). Spectral features at 1737-1731 cm^{-1} are indicative for glyceryl esters typically found in paint binding oils. The features near 1710 cm^{-1} are indicative of carboxylic acid groups (van der Weerd et al. 2005). The features between 1600 and 1500 cm^{-1} point to metal soaps (van der Weerd 2004; Osmond 2014; Hermans 2017). The FTIR spectrum of a sample (A) from an area without delamination displays small peaks that could be indicative of zinc soaps (Hermans 2017, Osmond 2014). Sample A is multi-layered, but without the soft black paint layer (numbered 2 in the illustration) (Figure 12). Sample B taken from exposed ground in an area with delamination shows a similar profile to sample A (Figure 11). Sample (C) was taken from a residue of the background colour in a delamination area, still connected to the ground. The peaks in the soap region are distinctly higher in this sample. The double peaks in the absorption region of 1550 to 1530 cm^{-1} in A, B and C match the spectrum of a zinc azelate reference (Osmond 2014). This would correlate to the high peaks of azelaic and related diacids in the black paint layer (Figure 10). Recent studies by Hermans and Helwig (2020) point out that crystalline zinc soaps of long chain fatty acids (type A) will also show a double peak but the saturated fatty acids have a low relative concentration in the mobile phase originating from the black paint layer. Sample D was taken from the upper part of a delaminated area and only the light yellow uneven surface was analysed.

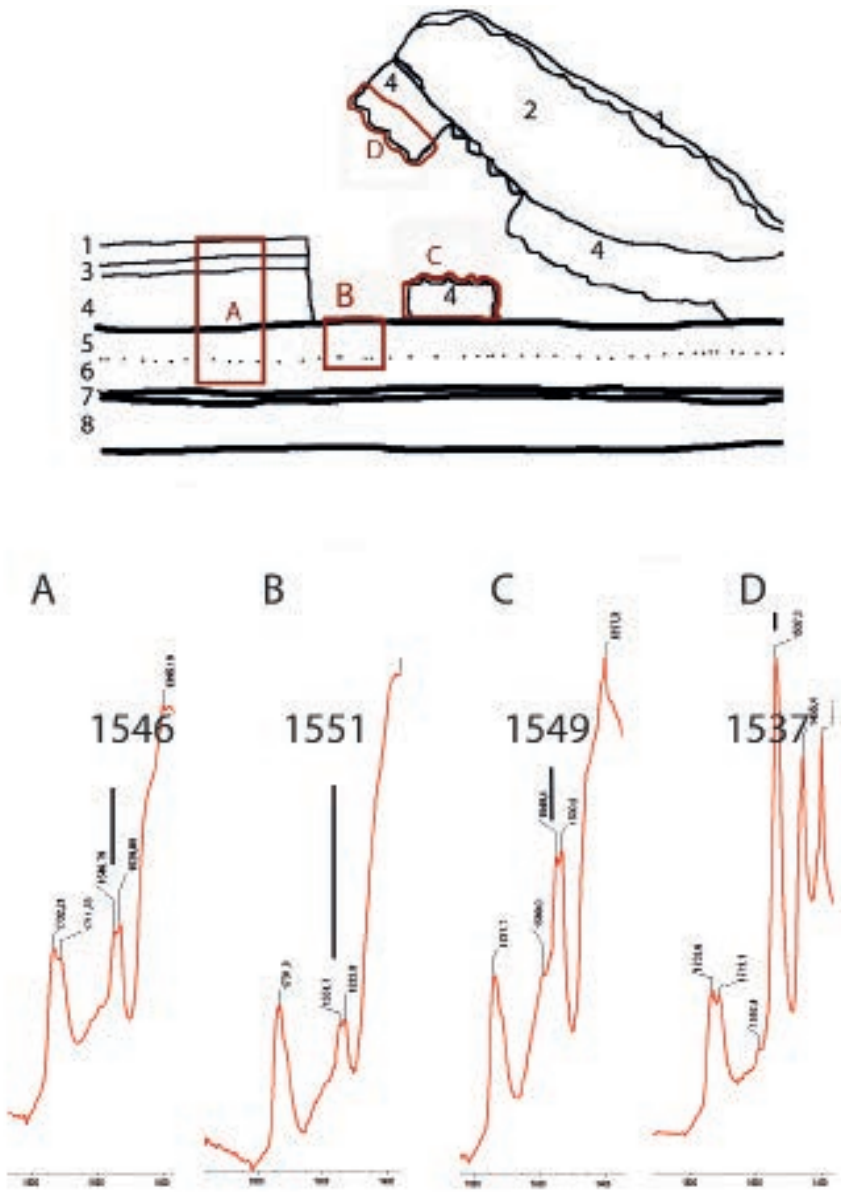

Figure 12. Simplified diagram of the layer structure and the position in the layer structure of sampling for the ATR-FTIR analysis. Details from the FTIR spectra focusing on the range with peaks indicative of soap formation. Illustration: Ida Bronken. Spectra: Calin Constantin Steindal.

The FTIR of D shows an absorption band of high intensity with a maximum at 1537 cm^{-1}, typical for zinc soaps of saturated fatty acids (the type B of Hermans and Helwig 2020). The sampling area is indeed rich in Zn as the EDX map shows (Figure 7). We infer that a high proportion of these type A metal soaps developed in area D near the interface. In general, the formation of zinc soaps will have weakened the interface leading to a loss of adhesion with delamination as a result due to the increase in volume and changes in rheology.

Discussion

In order for metal soaps to form both fatty acids and metal ions need to be present in the paint structure. Analysis of the main layers in Peinture has shown

that the upper soft black paint has a surplus of oxidised oil derived materials, but minimal soap formation (Figure 10 and 11). It is not known how many fatty acids were hydrolyzed from the glycerol esters, but over time this will, in theory, increase, and contribute to some extent in creating additional mobile fractions. In the underlying structure, there should be an abundance of metal ions from the lead- and zinc-containing pigments (Figure 8). The study has identified clear differences regarding soap formation in the delaminating areas and in the stable paint areas (Figure 12, C, D and A). In the samples from the delamination area, there are double peaks indicative of azelaic zinc soaps possibly in combination with type A soaps of saturated fatty acids. In layer D a sharp peak indicative of crystalline palmitic and stearic acid soaps of the B type are present (Hermans and Helwig 2020).
There are clearly less soaps in the paint layers that are not covered with the soft black paint (Figure 12 A). This supports the hypothesis that the soap formation is more active at the extended interface between the background colour and the soft black paint.

We cannot dismiss the possibility that some fatty acids from the ground and the background paint itself might have contributed to some extent to the soap formation. The soft black paint definitely creates a more reactive interface as shown by the FTIR spectra and the py-GC-MS analysis. These results support the assumption raised in earlier studies by Rogala et al. (2010) and Helou-de la Grandière et al. (2008) on delaminations and their relationship to the degradation issues of either malleable or fatty acid rich layers. The findings uphold how important it is to understand the build-up of a painting and of the combination of materials. The first hypothesis that the delamination could be due to lead soaps was found to be incorrect. The intermediate zinc containing paint layer played a much more active role than anticipated.

It would be interesting to follow up this study with an investigation of the transparent web pattern on the ground with FTIR. Without further analysis, it is not clear if this material has developed into soap or not, but we can still speculate that this transparent web will not improve the adhesion in the layer structure. Whatever the local chemistry in the web pattern, we infer that it is part of the reason for an increase in delamination of the upper paint layers. This, together with the volume increase in the zinc soaps, will weaken the contact between the paint layers and push them apart.

Severe delaminations have been observed in Soulages paintings in Norwegian and Finnish collections (Helou-de la Grandière et al. 2021). Mobility within the paint and the development of soaps are believed to increase with higher relative humidity (RH) (Noble 2019). Another factor is the intrinsic instability of already developed soaps or mobile fractions that could have been formed in the layer structure. It is important to provide a stable climate with as little physical stress to the structure as possible. First instincts will therefore be to glaze the painting, and thereby minimize the risks for the structure. This is not a straightforward decision to make though. With what we know about the artistic intent, it is not optimal to glaze the painting. For the right viewing conditions of the surface other options must be discussed. If possible, the overall museum environment should be considered. Many museum collections are opening the outer parameter of their relative humidity control, allowing up to 60% RH (Ashley-Smith et al. 2013). This raises the question whether some degradation processes of modern paintings might possibly react faster with higher RH. Over time, do we know enough about to what extent the gain for a cut in energy consumption is weighted against a potential loss of the cultural heritage value of modern paintings? How much might the chemical process be accelerated at higher relative humidity or the increase in conservation treatments? It is probably impossible to answer this without more research. But it is undoubtedly an important aspect of providing optimal preservation for years to come. Multidisciplinary research should be a guide in discussions about optimal preservation of modern paintings in the future.

If there is suspicion of soft and sensitive oil paints, it will be beneficial to look at both the storage situation and climatic conditions. Is it possible to lower the general humidity in the museum below or to 50% to lessen the risk of increased soap formation and hydrolysis? If the paint has a tacky surface it will be beneficial to provide a dust protection in storage. This will minimize the need to dust the surface to prevent the dust particles slowly embedding into the upper paint layer. These measures might lessen the need for adding optium or other type of glazing to the frame.

Conclusion

This case study has shown that zinc soap formation at the interfaces to the zinc white layer has led to delamination, primarily away from the ground. The fact that delamination is only occurring in regions with a black upper paint layer, suggests that the black paint is playing a role. This paint was found to be pigmented with bone black and ochre, it was soft and poorly cross-linked. The mobile acidic fatty acid content of the black paint is thought to be the main factor contributing to the zinc soap formation. This type of case study enhances our understanding of the particular combination of original paint properties and those developing upon maturation that influence the layer adhesion. Delamination is a severe and degrading condition of the painting surface that should be limited if appropriate museum conditions are chosen, particularly for modern art collections. Our recommendation is to consider the overall climate in the museum and communicate widely to all the museum staff both why and how sensitive the layer structure of similar modern paintings can be.

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Experimental

Fourier Transform Infrared spectroscopy (FTIR)
FTIR spectroscopy measurements at the University of Oslo facilities were carried out in attenuated total reflectance (ATR) with a IS50 Thermo scientific Nicolet continuum FTIR microscope equipped with a Ge crystal with a resolution of 4 cm−1. Spectra were collected using 32 scans from 4000 to 400 cm-1.

Scanning electron microscopy energy dispersive X-ray spectroscopy (SEM-EDX).
A FEI Quanta 450 scanning microscope coupled to an X-MaxN Oxford analyser 50mm2 was used for SEM–EDX. Paint samples were embedded in Technovit 2000 LC, and dry polished.

Pyrolysis- tetramethylammonium hydroxide -gas chromatography-mass spectrometry (Py-TMAH-GC-MS)
The pyrolysis-TMAH-gas chromatography-mass spectrometry analyses were performed on a Thermo Quest GC-8000 equipped with a Supelco column Equity®-5, Capillary GC column 30m, I.D. 0.25mm, df 0.5 interfaced with a MS MD-800 (Keulen, van 2014).

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SOULAGES' *PEINTURE 12 MARCH 1960*: DIAGNOSTIC ANALYTICAL STUDIES AND TENTATIVE CONSOLIDATION OF MAJOR CURLED-UP DELAMINATED AREAS

Abstract

The paper describes one of the most extreme forms of delamination seen in works by Pierre Soulages. It concerns a painting titled with its date of creation *Peinture, 162 x 200 cm, 12 Mars 1960* presently in the Sarah Hildén Museum in Tampere Finland. The delaminating surface paint has formed open wounds with curled up paint revealing an interface with the commercial ground where loss of cohesion started. Simultaneously, the upper bone black paint layer is forming acidic oxidized oil-derived exudates that also penetrate the lower paint layers. Imaging microscopic and spectroscopic methods reveal details of a dynamic process of delamination with paint consistency changes and mixing of layers near the delaminating interface during loss of cohesion. First successful experimental consolidation tests to reverse the open wounds were successfully carried out.

Introduction

Pierre Soulages (b.1919), still active after eight decades of work and the most renowned French painter alive today, is known for his exclusive use of the colour black in non-figurative works. He began his career with black oil paint strokes that contrasted and overlapped with lighter grey, yellow ochre, red or blue paint. Those paintings played an important role in the development of a new form of abstraction based on marks, lines and tracks of painting tools in the 1950s. Soulages developed large tools, used broad brushes, and adapted his oil media to render his tool traces visible. Unfortunately, a small number of oil paintings made in 1959 and 1960 are showing signs of severe damage in the form of fissures, cracks, and delamination, with extreme lifting of the paint layers. The cause for the appearance of these disturbing phenomena is thought to be the reactivity of underlying oil paint layers with the ground. These phenomena are particularly prominent in a painting in the collection of Sara Hildén in Tampere, Finland (Fig.1). The difference between the condition of *Peinture 12 mars 1960* recorded previously and its disastrous present state provided the rationale for a detailed multispectroscopic and microscopic study. The affected areas were compared with those in good condition. Raman spectroscopy, imaging Fourier Transform Infrared (FTIR), Scanning Electron Microscopy (SEM) and Gas Chromatography -Mass spectrometry (GC-MS) were applied together to identify and determine the distribution of organic and inorganic materials in selected cross-sections and samples relevant to the understanding of the problem of the delamination. The study presented here is performed to provide a scientific examination of the observed phenomena and to assist in the development of a conservation strategy. Initial conservation experiments to explore the counteracting of the lifting of paint layers are reported.

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Keywords:
Pierre Soulages; delaminating paint; exudation; loss of cohesion; medium acidification; consolidation.

Figure 1. Areas of lifted paint on *Peinture 12 mars 1960* by Pierre Soulages (162 x200 cm, oil on canvas, Sarah Hildén Museum, Tampere, Finland). Photo of the painting (A). Drawing of the main paint strokes and areas of damage with numbers indicating the sample positions (B). Major delamination area with curled up paint (C). Impasto and exudate drip in daylight (D) and fluorescent light (365 nm) (E). Photos: Hélou-de La Grandière and Boon.

Degradation phenomena of some Soulages paintings

The delamination phenomena have been seen in several of Soulages' paintings from 1959 and 1960. In his painting at the Musée d'Art moderne de Paris, *16 Décembre 1959*, the lead white priming was suspected to be linked to cleavage defects (Hélou-de La Grandière et al. 2008). In this painting and some others dated around Decembre 1959, the commercial ground from colourman Lefebvre-Foinet with plumbonacrite and lead soaps was thought to be the cause of the delamination. Paintings by other artists who used the pre-primed canvases from this paint supplier also suffered various related defects (Hélou-de La Grandière et al. 2008, Hélou-de La Grandière et al. 2009, Corbeil et al. 2011; Bronken and Boon 2014; O'Malley 2019).

In addition to the delamination phenomena, the surface layer in some paintings from around 1959-1960 have shown dripping exudates. A Soulages painting titled *Peinture, 130 x 162 cm, 17 mars 1960* in the Art Institute of Chicago has exhibited this defect. Specifically, an acidic fraction that developed from oxidizing oil paint in the bone black paint appeared at the surface as dripping exudates (Boon and Lister, 2014). The same weeping degradation had also been observed in a contemporary work of Soulages (*Peinture 15 Décembre 1959*) from Toulouse, France (Hélou-de La Grandière 2017).

Also possibly linked to the colourman Lefebvre-Foinet, compositionally similar exudates have been found in paintings by Jean-Paul Riopelle (Bronken and Boon 2014) from the 1950s and in paintings by Karel Appel from that time, during his Parisian period (Bronken et al. 2019 ; Boeve-Jones et al. 2020). The damage concerns not only the change in surface condition of the works, but also inherently affects the paints, leading to softening of the oil paint internally, and the formation of new materials. Additionally, it causes internal weakening affecting the structure of impastos leading to loss of cohesion where paint layers tear and are lifting. These issues have been described as aspects of the “Montparnasse Disease” (Hélou-de La Grandière 2019).

Such defects developed over time in the paint layers, so it is difficult to determine cause and effect: Has painting technique played a role? Are the issues related to the drying conditions? Or environmental conditions? These questions are currently being studied in a PhD thesis project by the first author entitled "NOIRŒS”[1]. So far, each new case study is adding to the understanding of the degradation process, such as the painting from Tampere presented in this paper.

All of the earlier case studies were done during conservation treatments. They highlight the importance of the constitutive elements, with interactions between the industrial ground and the paints (industrial or mixed by Pierre Soulages himself). Although the focus is on paintings with conservation issues, not all paintings by Soulages from this period feature such signs of damage. There are as yet unknown factors involved.

The painting process of Pierre Soulages

To fully understand Pierre Soulages’ painting process, the first author had the opportunity to ask the artist about his methods since first meeting him in 2004. Priorly, Roger Vailland (1907-1965), a poet and friend of Soulages, was present in his studio during the creation of *Peinture, 200x160 cm, 27 Mars 1961*, and wrote a paper “How Pierre Soulages works?” (Vailland 1961). Because this painting is quite similar in composition, format, and was made not long after our case study Peinture, 12 mars 1960, the making process may have been very similar.

Vailland describes the scene, summarized as follows: In his large and sunny Parisian studio, Soulages takes time to prepare the materials and canvas surface before proceeding to paint. He feels that the ground is too greasy, so he first degreases it with a cloth and “an appropriate liquid”[2]. However, this degreasing goes too far, so, after a dozen minutes, he applies a kind of jelly with a brush to make the canvas more slippery again. Vailland then describes the preparation of all the colours by Soulages: *“he places a tank filled with ivory black paint, which he finds to be too thick and therefore thins by adding “an oily liquid”. In another bin he empties a large tube of white oil paint*”[3]. Then, he mixes the colours on transparent glass. The colours are placed, scraped off and replaced on the canvas over the course of three hours, using brushes and a rubber slab.

This eyewitness account highlights how Pierre Soulages paid attention to the quality of the ground even when commercially manufactured. It also shows that he created his own melange using commercial paint tubes and additives to obtain the desired consistency. Of course, sixty years later and after more than a thousand paintings, Pierre Soulages does not recall the exact recipe of this “appropriate liquid”, the “jelly” nor the additives in the preparation of the paints. However, he remembers which materials from Lefebvre-Foinet he used - three different types of commercial pre-primed canvasses (available with variable porosities). He also recalls that he chose the “fatty preparations”, because he wanted to avoid the excessive absorption of binders and to avoid a matte appearance to the paint. According to his recollection, this type of preparation consisted of three coats of lead white ([Soulages 2004], de La Grandière 2005, Hélou-de La Grandière 2019). The contemporary suppliers confirmed that each was applied as soon as the previous one had dried on the surface (de La Grandière 2005:58).

This priming process from the colourmen suggests short drying times between each layer, a procedure that can affect the lead white pigment (Leback-Stiwell 1989; Zucker 1999). In France, the lead white ban in 1948 led to a number of manufacturers going out of business. Thereafter the supply of the lead white became problematic and the quality of canvas preparations very variable, as was confirmed by the colourmen working in Paris at that time (Edouard Adam, Dominique Sennelier, see de La Grandière 2005). Soulages has himself blamed Lefebvre-Foinet:

« At the end of the fifties, I had, as well as some comrades who had the same supplier as me, yet very famous, some canvases whose priming layer dissociated itself from the support[4]» (Soulages, 1994: 54).

Present condition of the painting

Peinture 12 mars 1960 was bought soon after completion by the Finnish businesswoman and art collector Sara Hildén (1905–1993) and presently resides in the Sara Hildén museum in Tampere. The painting has been kept in storage for years. Figures 1A and 1B illustrate the extent of the damaged areas on this painting. Figure 1B is a map of the damage observed on the painting with sampling areas marked as S1, S2 and S3. Lifting and severe delamination of the paint layers, deformation, softening of the layers, accompanied with dripping of medium rich exudations and changes in surface quality (excessive gloss) appear everywhere where black surface paint is present, except where the red-ochre-brown paint is the undercoat, as well as in thinly-painted parts. The delaminated area that is about 15cm in length in Figure 1C shows surface black paint that is acutely curled up, revealing the off-white underpaint beneath. In general, the upper black layer suffers from a strong modification of its characteristics as wave-shaped deformations are visible and correspond to a softening of the paint. These deformations were observed to evolve rapidly when the painting was moved from storage to the museum space for examination - possibly due to a sudden change in environment. Softening seems linked to the lifting process and is also coupled with a strong increase in the glossiness of the surface, which emits a strong bluish fluorescence under UV light (365 nm). Ultimately, the softening either leads to a sticky dust-attracting surface or to exudation of an UV fluorescent fluid (Fig. 1E).

Paint build-up and spectroscopic studies

Samples could be taken from several delaminated areas (S2 and S3), the exudate and an undisturbed black painted area near the right tacking margin (S1). Sample areas were photographed in situ. 3D-Hirox-microscopy was performed in the laboratory before further microsampling, embedding in Technovit 4000, UV-curing for 20 minutes and subsequent hand-polishing of the blocks with a series of micromesh polishing clothes (1800 – 8000 mesh) to obtain cross sections suitable for analytical studies. The cross sections were investigated at the Art Technical Laboratory in Bern with visible light, UV light, Raman spectroscopy and FTIR microscopy before investigation by SEM under electron back scatter conditions (BSE) and Energy Dispersive X-ray element mapping (EDX). Subsamples were also taken for investigation by GC-MS using the on-line analytical transmethylation protocol (Van Keulen 2014). For detailed experimental conditions see section *Equipment.*

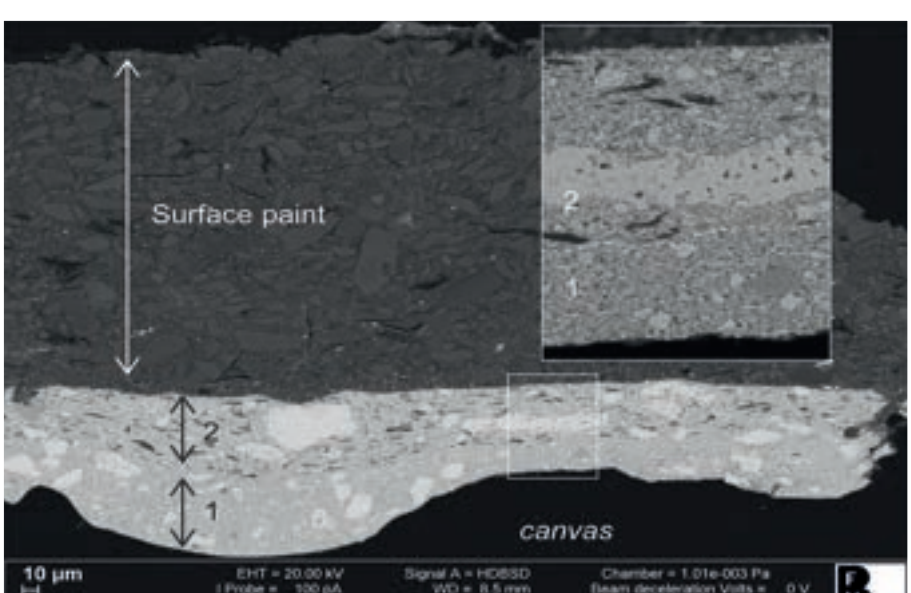

Figure 2. SEM-BSE image of the paint layer buildup near the right-hand side tacking margin (S1 in Fig 1B) showing a double ground with layer 1 with large fragments of lead white in a finer matrix and layer 2 with lead white and elongated particles of talc (dark in SEM-BSE). Layer 1 follows the canvas surface. A thick layer of bone black paint forms the top layer. Photos: Scherrer & Boon.

All cross sections were studied under visible and UV light. However, the layer structure and particle composition are best understood through Scanning Electron Microscopy imagery, particularly electron backscatter images (SEM-BSE). The cross section of the sample at the tacking margin (S1), shown in Figure 2, illustrates the ground and a simple black paint layer, which overflowed from the composition. Figure 2 is composed of two parts: an overview and an inserted magnified area of the ground layers. The priming is a double-layered ground consisting of a lower layer (1) 30-40 microns thick, of fine crystalline lead white mixed with large lead white chunks and occasionally a rounded particle of barite (grey under BSE). The second, similar lead white layer (2) above shows many elongated hydrated magnesium silicate particles of talc (black under BSE). A thick layer of black paint (120 micron) with particles of bone black (calcium and phosphorous detected with EDX) is present. The painted area at the tacking margin is solid and shows no sign of weeping or loss of adhesion. This part of the painting will be compared with those areas where the delamination occurred.

The SEM-BSE image in Figure 3 of the cross section of the second microsample (S2) taken from a slightly lifting paint area shows a more complete set of paint layers. Layer 1 is broken off at the bottom on the right-hand side upon sampling. Layer 2 is marked by the elongated talc particles. The first layer applied by Soulages (3) is a finely-divided, very well-sorted lead white layer corresponding to the off-white underpaint visible on the surface of the painting below the whole composition (Fig. 1A). This is followed by the black paint, divided in two layers in our examination: layer 4, considered to be a transition zone with a mix of lead white from layer 3 and bone black particles suggesting a wet-in-wet technique, and then layer 5, composed of black paint alone. The image taken under UV light shows that layer 3 has a slightly different fluorescence hue compared to the other layers. This layer (3) shows the FTIR characteristics of aliphatic chains at 2953-2889 cm^{-1}(vC-H), esters at 1765-1722 cm^{-1}(vC=O), lead soaps at 1565- 1504 cm^{-1}(vC=O) and lead white carbonate at 1455-1360 cm^{-1}. The top layer has a peculiar blue fluorescent and transparent interlayer between layers 4 and 5 (denoted with a star). This layer has a strong unique absorption in the FTIR range from 1724-1660, pointing to ketones and acids upon FTIR mapping. This could be an entrapped exudate.

The stratigraphy of this cross section is remarkable. The top layer (5) is curled up together with the layer (4) underneath. The particles in layer 3 in the middle of the section are oriented like the ones from layers

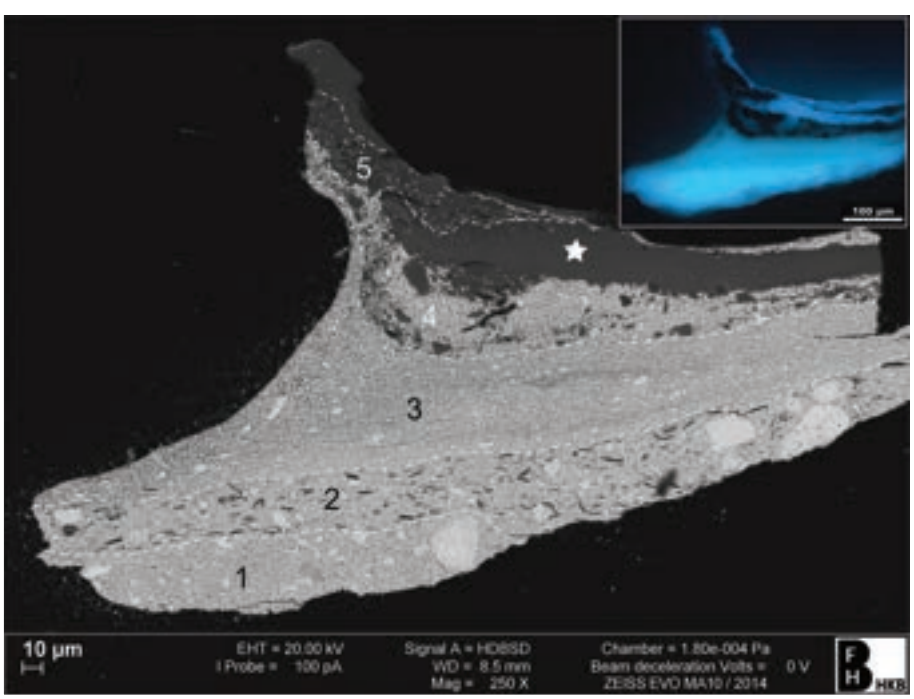

Figure 3. SEM-BSE collated image of the paint layer buildup in the center of the painting (S2 in Fig 1B). Layer 1 and 2 form the double ground. Layer 3 is the off-white underpaint used to create the background. Layer 4 is a wet-in-wet layer of 3 and 5. Layer 5 is the black bone black surface paint. The insert is a microscopic photo under UV light. The star is a carbon rich inter layer. Photos: Scherrer & Boon.

1 and 2, but are almost perpendicularly oriented on the left side (dashed line left) where it became exposed to the open air during delamination. These changes in stratigraphy suggest that layer 3 must have undergone a change in consistency while the area was lifting.

A third sample (S3) investigated was a paint flake that had broken off in the major delamination zone shown in Figure 1C. Microsamples were taken from this paint flake for examination with imaging-light microscopy, imaging FTIR-microscopy and SEM-EDX, to determine the paint layer build-up and composition. Raman spectroscopy was employed for the identification of specific mineral phases.

Microscopic examination with 3D-Hirox microscopy showed the off-white underside as a corrugated surface covered with a film of light-reflecting "wet-looking" exudates. The surface of this off-white paint exhibits distinctive ridges (Fig. 4), which are known as cohesion fillets in adhesion science (SpecialChem 2021; Pocius and Dillard 2002). The pattern of these ridges suggests that the underside had at some point become softened, with changed viscoelastic properties leading to a loss of cohesion and to detachment from the remaining ground below. Certainly, the curling of the lifted paint borders indicates that the delaminating paint stack was ductile during the separation process. A similar corrugated surface was present in another sample from a different zone of lifted paint. Light reflected from this surface also suggested the presence of a thin coating of light-reflecting organic materials.

The SEM-BSE picture of the cross section of the paint flake S3 (prepared through one of the ridges) shows the loss of a clear layer structure (Fig. 5). The top paint layer (5) and the layer below (4) are still discernible but layer 3 and below appear to have become an unexpected mixture of layers 2 and 3 (indicated as 2+3). The dark flat talc crystals of hydrous magnesium silicate present in the second ground layer (2), and identified with Raman spectroscopy, are suggestive markers for an increasing fluidity that had affected the second ground layer and the lower part of Soulages' off-white underpaint. The bottom of the cross-section (the interface where the delamination has occurred) shows depletion in solids.

The cross section was investigated with SEM-EDX element mapping and Attenuated Total Reflection (ATR)-FTIR-microscopy. The footprint of the ATR crystal of the FTIR microscope on the cross section is shown as a white-lined box in the SEM-BSE image

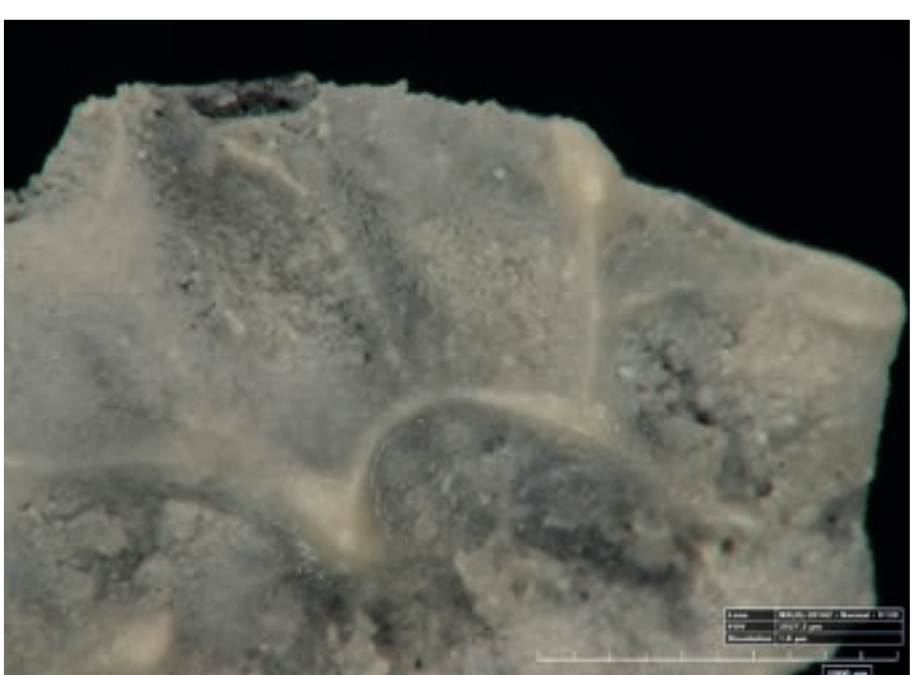

Figure 4. Hirox 3D-image of the underside of a paint flake sampled from the major area of delamination (S3 in Fig 1 A) showing ridges that suggest plastic deformation during delamination from lower layers. Photo: Boon.

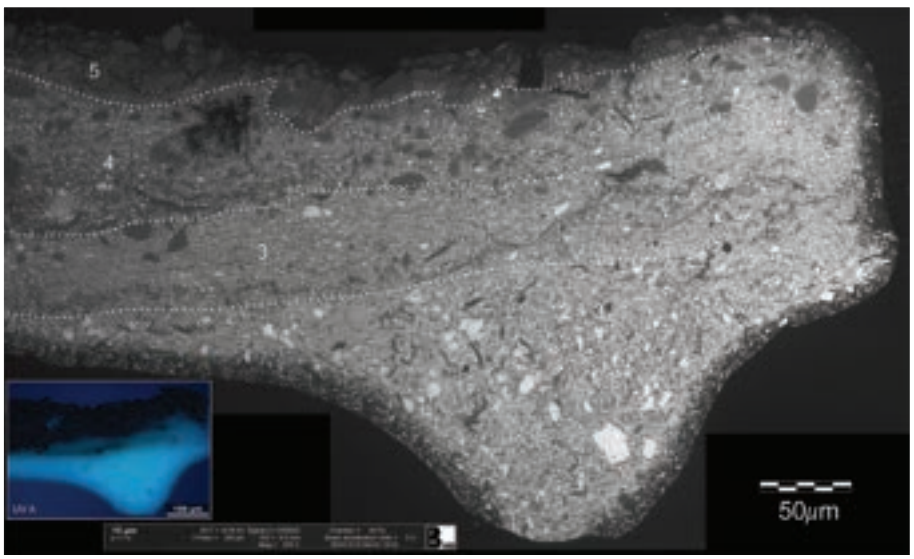

Figure 5. SEM-BSE image of a cross section through a ridge in the delamination zone. The numbers correlate with the layer buildup in Fig. 3. The layer 2+3 is a mixture of layers 2 and 3. Photo: Scherrer & Boon.

in Figure 6. This area was chosen for FTIR imaging because it includes part of layer 4, layer 3, the mixed layer (2+3) and the thin delamination zone (D).

Figure 6 combines the maps from FTIR-Focal Plane Array imaging and SEM-EDX. The SEM-EDX imaging maps show the distribution of lead (Pb) in purple, and mineral phase maps[5] of magnesium silicate (talc), calcium phosphate (bone black) and barium sulphate (baryte). The talc is the marker of the second ground. The maps represent the relative signal intensity of the spectral windows denoted above each map.

The FTIR maps of carbonates at 1464-1334 cm^{-1}(Fig. 6), the map of general binder features at 2949-2898 cm^{-1} (asymmetric CH2 vibrations) and esters at 1761-1725 cm^{-1} (vC=O) correlate well with the lead distribution (Pb M-lines), pointing to lead carbonates and lead soaps. The FTIR map of saturated fatty acid soaps (lead stearates) 1545-1493cm^{-1} correlates well with the off-white underpaint in the top part of the stratigraphy. The lower part of the stratigraphy with the talc (layer 2+3) shows some differences in distribution of (lead)-carboxylates (1576-1517 cm^{-1}) and acids (1735-1691 cm^{-1}). This difference in lead soap distribution with respect to the off-white paint could point to an alternative structure of the lead in the lead soap of layer 2+3 (Hermans 2017). The increased acidity at the bottom could be linked to the identified acidic molecules observed with GC-MS (see below). The ~10-micron-thin delamination zone represents an area of strongly-reduced pigment and binder content (see fig. 6). Indeed, this boundary layer seems highly weakened.

Figure 7 illustrates a SEM-BSE image at high magnification of the boundary layer of paint flake S3 with a thickness of 10-20 microns. The elongated crystals within the delamination zone are interpreted as cerussite. The FTIR images in Figure 7 show the distribution of binding medium features (1759-1685 cm^{-1}: C=O from esters), the distribution of carbonate (1459-1325 cm^{-1}) and hydroxyl groups (3564-3491 cm^{-1}) respectively. The boundary layer is depleted in hydroxyl group features. It has a higher concentration of cerussite relative to the layer above with hydrocerussite and plumbonacrite both identified with Raman spectroscopy (785 nm). Hydrocerussite and plumbonacrite are stable under alkaline conditions but cerussite [$PbCO_3$] is more stable under weaker alkaline conditions with a boundary in the phase diagram at about pH 8.5 (Taylor and Lopata 1984). The distribution of these lead mineral phases suggests that the cohesion loss, leading to weakening of the interface to ground layer 1 and the process of delamination, could be the result of pH changes. Studies with micro-X-ray diffraction would be desirable for further confirmation of the changing mineral phases.

Binding medium analysis

The molecular signature of the delaminated paint layer and the exudate were investigated by GC-MS on-line analytical transmethylation protocol

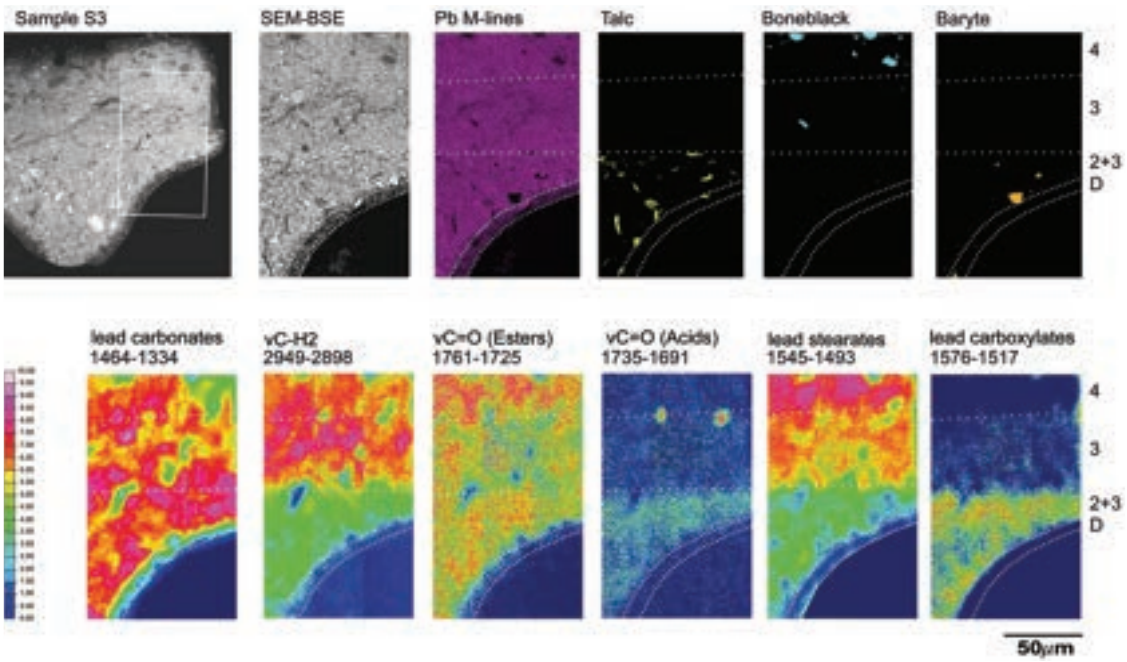

Figure 6. SEM-BSE overview and detail of sample S3 with SEM-EDX element and phase maps, and FTIR-FPA images of the right-hand side of the cross section in Fig 5. FTIR-FPA images represent the relative intensity of the corresponding spectral window denoted above each map. Dashed lines and associated numbers on the right-hand side indicate the various paint layers and the delamination zone (D). Illustrations: Zumbühl & Scherrer.

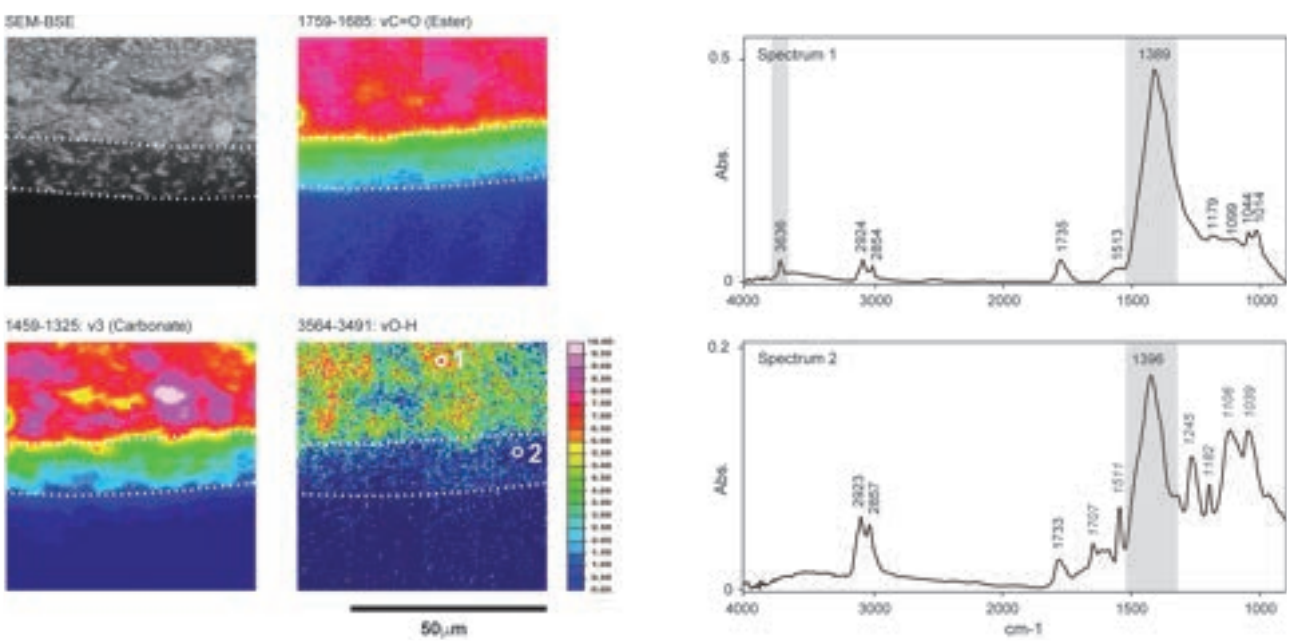

Figure 7. SEM-BSE and FTIR-FPA images of the outer layer at the delamination interface of sample S3. FTIR-FPA images represent the relative intensity of the corresponding spectral window denoted above each map. The numbers within the vO-H map correspond to the extracted spectra 1 and 2. Peaks with the grey background notify the signature of the lead white pigment. Peaks labelled with italic numbers signify the signal of the embedding resin. Illustrations: Zumbühl.

(Van Keulen 2014). The total ion current (TIC) chromatograms of both samples are almost identical in composition, although the paint flake has a higher relative concentration of palmitic, oleic and stearic acids. The TIC of the exudate in Figure 8 shows the distribution of fatty acid and diacid methyl esters. Peak numbers in Figure 8 are listed in Table 1. Mass spectra were identified by comparison to the mass spectral data atlas of J. van den Berg (2002), data from NIST (www.nist.gov) and by mass spectral interpretation. Note that oxy- and hydroxyl-groups are also methylated under the analytical conditions. In summary, a series of shorter- (C6-C10: nr 4, 5, 7, 9) and longer-chain fatty acids (C16-C24: nr 19, 22, 30), a dominant series of diacids (C4-C11: nr 6, 8, 12, 14, 15, 17, 18) with a Gaussian distribution, and several hydroxyl-, keto- and epoxy- stearic acids (nr 23, 24, 25, 26, 27, 28 and 29) were identified. The identification of glycerol (as methoxy derivatives nr 1, 2 and 3) points to preservation of some acylglycerol esters (as is corroborated by the FTIR data: Fig 6 D3). A preservation of the biological ester bonds would imply that the acid groups are mainly from the various diacids (formed by double bond oxidation) and much less by hydrolysis of ester bonds. Penetration in the alkaline lower paint layers, however, would certainly lead to hydrolysis of the ester bonds, thus making lead soap formation easier.

Discussion

Peinture 12 mars 1960 is a painting with severe damage due to weeping black surface paint and numerous areas of delamination and weeping black surface paint. The exudate shows characteristics of relatively high amounts of diacids and various oxy- and hydroxy-stearic acids in a free or glycerol ester form. We infer that these oil-medium-derived compounds not only appeared at the surface, but have also penetrated the underlying paint layers, where they reacted with the lead white mineral phases to form lead soaps. The diacid distribution from the surface paint shows a Gaussian distribution around the C9-diacid (azelaic acid), which suggests a thermal isomerisation of double bonds (Mills and White 1999; van den Berg 2002). The latest black paint layer is described by Soulages as the “black magma” created by himself with a mixture of ivory black pigment and linseed oil boiled with litharge (lead oxide) with addition of Flemish Siccative Medium from Bourgeois Ainé (Hélou-de La Grandière 2019: 394). Heating and boiling of vegetable oil leads to major chemical changes in composition due to thermo-oxidative stress (van den Berg 2002; Picariello et al. 2009). No evidence for resins was found in the GC-MS of the exudate or in the surface paint from *Peinture 12 mars 1960*, which made the addition of Flemish Siccative Medium questionable. In hindsight, GC-MS data of the lower-lying paint and ground layers would have been useful but imaging ATR-FTIR of cross sections has shed light on aspects of the chemistry of the layers.

The double ground of *Peinture 12 mars 1960* shows unique features that have not been reported before. The first ground layer is composed of coarse-grained lead white with some rounded barite particles, presumably used as extender. The second ground shows a relatively large amount of talc particles in a similar lead white composition. As the canvas does not have a stamp from the supplier, the question arises as to whether these grounds are indeed from a commercially-primed canvas of Lefebvre-Foinet, used quite frequently by Soulages by the end of the 1950s (Hélou-de La Grandière 2019: 395). This question remains open, requiring further comparative studies.

The first paint layer Soulages applied on *Peinture 12 mars 1960* is an off-white paint that consists of a fine-grained, well-sorted lead white typical for chemically-produced lead white (Corbeil and Sirois 2007). Delamination in the painting occurred exclusively where this paint layer was applied to the ground. The cross section in Figure 3 shows a relatively thick layer of degraded off-white paint where the lifting has occurred. FTIR mapping shows an abundance of lead soaps and oil binder components in this layer relative to the ground layers. The zone on the left has a different orientation of lead white particles, suggesting that underneath the lifted area the paint may have become more fluid. The morphology at the bottom of the paint flake from the major delamination zone shown in Figure 4 also suggests a difference in consistency when the lifting took place. The cross section made through an area with cohesion fillets of this paint flake (shown in Figure 5) makes the process during loss of cohesion visible in its distribution of the mineral particles from layers 2 and 3. The distribution of talc particles from layer 2 are mixed into layer 3, which is interpreted as a possible “fluidization” of the interfacial zone before or during the delamination process. Recently, evidence for a change in rheology at delamination interfaces has been reported by Bronken et al. (2019) on a delamination interface in

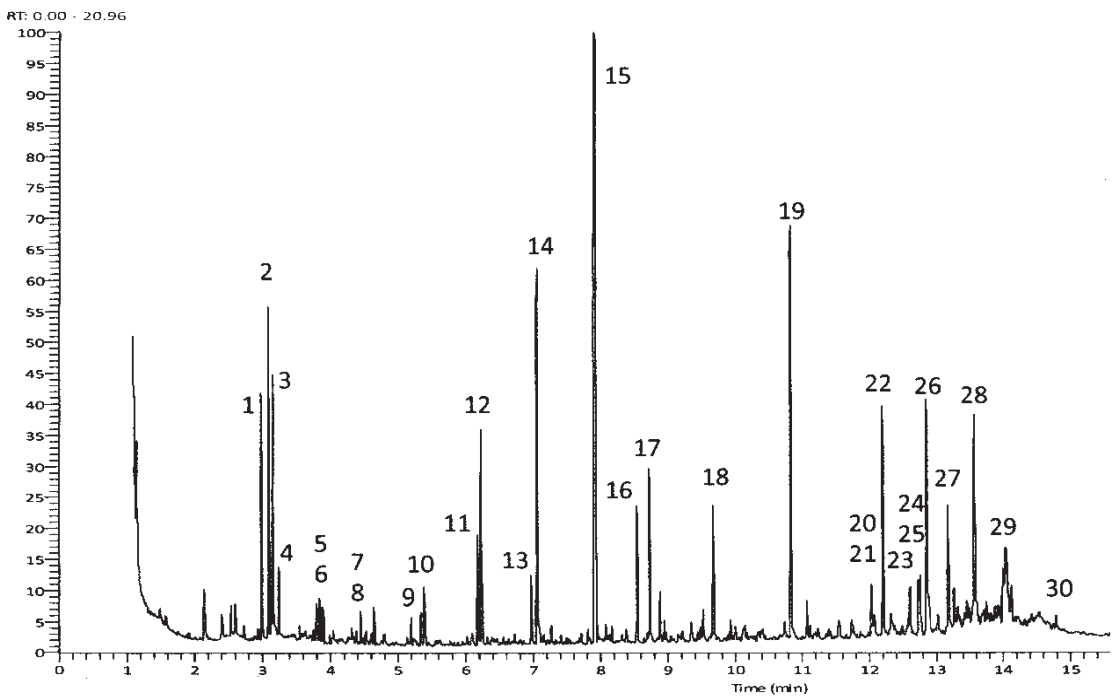

Figure 8. Total ion current profile of GC-MS data from the exudate. Peak numbers of compounds listed as identified compounds in Table 1 (right). Illustration: Boon.

a painting by Asger Jorn from 1957 and by Bronken et al. (2021) on a delamination plane in *Peinture, 10 Décember 1954*, by Pierre Soulages. More information on these interfaces in future studies should shed light on the dynamics of cohesion loss and subsequent delamination

The SEM-EDX maps and FTIR maps in Figure 6 illustrate a difference in chemistry between layer 3 and the new layer (2+3). There also is an ~10-micron-thin delamination zone present (Fig. 7) with a much lower density. Lead white (FTIR carbonate feature) and lead soaps are the dominant components in layer 3 and layer 2+3, but less so in the delamination interface of the cross section. The difference in binding medium components i.e., aliphatic features, acids and esters, and other lead soaps, can be observed, but the mechanism remains uncertain.

The chemistry of the lead white in the delamination zone (Fig. 7) is different. Cerussite (lead carbonate) was found there while the layer above (2+3) consists of hydrocerussite (lead white) and plumbonacrite. This transition is indicative of less basic conditions in the outer zone during delamination. Our main conclusion is that loss of cohesion is not just a physical process of tearing but a much more chemically-reactive process of weakening at the delamination interface in the case of *Peinture 12 mars 1960*. It is inferred that a penetration of mobile medium constituents from the black surface paint plays an important role in the lead soap formation of the lower layers and the formation of a more fluid delamination interface. Physical forces subsequently lifted the paint at its weakest point. The cross sections in Figures 3, 4 and 5 illustrate the various stages of lifting.

Number of identified compound in Fig 8	Acronym (non-methylated)
1 1,3-dimethoxy-2-propanol	GLY
2 1,2,3-trimethoxy-propane	GLY
3 2,3-dimethoxy-propanol	GLY
4 hexanoic acid, methyl ester	C6 F
5 heptanoic acid, methyl ester	C7 F
6 butanedioic acid, dimethyl ester	C4 DF
7 octanoic acid, methyl ester	C8 F
8 pentanedioic acid, dimethyl ester	C5 DF
9 nonanoic acid, methyl ester	C9 F
10 hexanedioic acid, dimethyl ester	C6 DF
11 8-methoxy-octanoic acid, methyl ester	omega OH/O-C8 F
12 heptanedioic acid, dimethyl ester	C7 DF
13 9-methoxy-nonanoic acid, methyl ester	omega OH/O-C9 F
14 octanedioic acid, dimethyl ester	C8 DF
15 nonanedioic acid, dimethyl ester	C9 DF
16 tridecanoic acid, methyl ester	I.S. C13 F
17 decanedioic acid, dimethyl ester	C10 DF
18 undecanedioic acid, dimethyl ester	C11 DF
19 hexadecanoic acid, methyl ester	C16 F
20 octadecenoic acid, methyl ester (cis/trans)	C18:1 F
21 octadecadienoic acid, methyl ester	C18:2 F
22 octadecanoic acid, methyl ester	C18 F
23 hydroxy-octadecenoic acid, methyl esters	OH-C18:1F (3 isomers)
24 8-methoxy-9-octadecenoic acid, methyl ester	OH-C18:1 F
25 11-methoxy-9-octadecenoic acid, methyl ester	OH-C18:1 F
26 10-methoxy-8-octadecenoic acid, methyl ester	OH-C18:1 F
9-methoxy-10-octadecenoic acid, methyl ester	OH-C18:1 F
27 9,10-epoxy-octadecanoic acid, methyl ester	9,10-EPOXY-C18
28 9,10-dimethoxy-octadecanoic acid, methyl ester	Di-OH-C18 F
29 9,10-dihydroxy-octadecanoic acid, methyl ester	Di-OH-C18 F
30 docosanoic acid, methyl ester	C22 F

Steps towards a conservation treatment

The painting has not been exhibited since 1986. The first serious defects in the form of lifting and dripping paint were noticed in 1995[6]. Since 1995, it was decided to record the condition very precisely, but not to treat the painting, in order to avoid a risk of successive inefficient treatments. This precautionary stance was useful in other similar cases and was justified since it guaranteed the ethical principle of reversibility. Unfortunately, during the two-decade-long period in storage in the museum in Tampere, the delaminated paint layer formed the open areas with curled paint seen in Figure 1A and Figure 9 in a process that appeared to accelerate in recent years. Treatment became urgent. After discussion with the curator, an experimental consolidation process could be started before all the information about the chemical process was available.

In order to stabilise and re-adhere the delamination, a compromise was sought to resolve the disparate behaviour of the paint film: the upper distorted paint was flexible while the paint remaining on the canvas was brittle. The aim was to re-adhere and bring the upper distorted areas back in line with the rest of the surface. The first step consisted of determination of the solvent and thermal sensitivity of both paint layers. Initial tests were carried out on the painted tacking margin. Only a few solvents were found to be safe to use without risk to the original paint layer: demineralized water; ligroin[7]; a solution of 70 parts ligroin to 30 parts alcohol (ethanol); and a 1:1 solution of water and alcohol. The paint was highly sensitive to raised temperatures (45°C is the softening temperature of the paint).

Figure 9. A short period of softening in an appropriate vapor atmosphere is sufficient to soften the curled paint for subsequent flattening (left- and right-hand side images). The image in the middle shows the before- and after-result of the repair. Photo: Hélou-de La Grandière.

The most challenging aspect was to flatten the somewhat malleable flakes. Figure 9 illustrates the chosen approach: in order to soften the paint while avoiding direct contact, the paint is exposed to solvent fumes locally by inverting a polyethylene cup over the targeted area, which contains a solvent infused cotton ball wrapped in fabric and suspended with string from the top of the cup. This micro-chamber delivers solvent vapours from a mixture of 80 parts ligroin to 20 parts ethanol. Only 10 seconds of exposure are necessary to affect softening in the paint, which retains flexibility for several minutes, allowing the curled flakes to be unrolled using a soft silicone spatula (a stiffer tool would mark the paint surface).

To select adhesives, tests done on the tacking margin revealed that few adhesives, which can be delivered in the limited solvents identified above, would adhere to the ground surface: Only Beva Gel® (Kremer), Klucel® G (in water or water/alcohol) and Lascaux Hydroground ® were suitable and effective (see Materials).

The consolidation was a compromise between good adhesive strength and an implementation compatible with the properties of the paint. An aqueous dispersion of Beva Gel® gave good results but was rejected because of its risky reversibility. Best results were obtained with Lascaux Hydroground ® (10% in water) plus a small portion of surfactant which strongly improves adhesion, probably due to a better wetting ability during the consolidation process (Triton® DF12, 2 ml in 200 ml solution). Previous experience supports this choice (Barabant and Hélou-de La Grandière 2012:326). The procedure involves two viscosities of the adhesive: diluted Hydroground ® in fluid form is inserted under the flake with a syringe and allowed to spread by capillary action. Then, a thickened formulation is applied under the flake (Hydroground ® thickened with 5 % by weight Klucel® in a 1:1 mixture with water and ethanol). Thanks to this thickened formulation, the adhesive does not spread beyond the lifted area, and its gradual drying can take place at the same speed as the flattening of the flake while it consolidates.

The paint is then laid down with heat (warm air from a Leister® gun) and pressure. The addition of Klucel® improves the viscosity and slows the drying time of the adhesive, while remaining compatible with the solvent. The initial tests using this consolidation method remained stable after 1,5 years, which is considered safe enough for further implement this treatment.

During flattening, the flakes appeared somewhat larger than the area of loss (Fig. 9) and required cutting the edges of original paint film by more than 1mm to reintegrate the flake into its original position: the white paint on the lower side of the flake apparently expands which explains the deformations of the paint impastos and curling. Due to this phenomenon, the flattened paint has lost its original thickness and surface texture; a process that is irreversible. Although the “open wounds” could be healed, the paint surface is left somewhat disturbed and damaged. The modified consistency of the paint in its thickness is also an irreversible defect. The surface intended by Soulages can never be fully restored to its original characteristics, and the stabilisation of the painting can’t be guaranteed after consolidation. This is an ongoing topic in the PhD project NOIRŒS.

Conclusions

The investigation of the open surfaces of the delaminated areas on the painting provided physical and chemical clues to the process of loss of cohesion, cleavage and subsequent distortion in the remaining flakes. Ductile ridges on the delamination surface and supporting microscopic, SEM-EDX and imaging FTIR data point to different viscoelastic properties at the interface of Soulages’ off-white paint and the second ground layer below. The off-white paint and the second ground layer marked by talc crystals have lost their internal consistency and have mixed either before or during the delamination process. The composition of an exudate and its black source paint points to a thermally-treated binder that dried and matured but developed a non-cross-linked oxidised and acidic mobile fraction. This mobile material appeared at the surface but also penetrated the layers below. Part of this material has apparently been trapped as lead soaps, but another part is thought to have accumulated within the paint composite, causing a mechanical weakening at the interface of the artist’s off-white paint and the ground below.

Experiments to develop a novel treatment method were tested on the painting to flatten and re-adhere delaminated areas. While this procedure was successful in stabilising the paint, the surface appearance of the affected areas has changed, demonstrating that the effects of the paint degradation cannot be entirely reversed.

Endnotes

1.The PhD NOIRŒS (acronym for Nouveaux Outils Interdisciplinaires pour la Restauration des Œuvres de Pierre Soulages / New interdisciplinary tools for the conservation of the works by Pierre Soulages) is a practice-led research doctorate in conservation affiliated with the Cy Cergy Paris University Graduate School of Humanities, Creativity, and Heritage. Under the direction of Thierry Sarmant, Mathieu Thoury (IPANEMA) and Lionel Simonot (Université de Poitiers), this work is supported by the Ecole Universitaire de recherche PSGS HCH Humanities, Creation, Heritage, Investissement d’Avenir ANR-17-EURE-0021.

2. « Pour rendre la toile plus glissante, il prépare une sorte de gelée ».

3. Personal translation of : « Soulages pose sur la table de marbre un bac rempli d'un magma noir d'ivoire. Il le trouve

trop dense. Il le rend plus fluide en ajoutant un liquide huileux. Dans un autre bac, il écrase un gros tube de blanc. »

4. « A la fin des années cinquante, j'ai eu, ainsi que quelques camarades qui avaient le même fournisseur que moi, pourtant très réputé, quelques toiles dont la couche picturale se désolidarisait du support »

5. EDX maps composed of several elements together representing one type of compound.

6. In 1995, painting conservator Kirsti Harva noticed exudation only from the paint layer. The drips were removed with a dry cotton swab.

7. aliphatic hydrocarbons without aromatics CAS Registry Number 8032-32-4.

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Materials

- BEVA Gel: Aqueous dispersion of ethylene vinyl acetate and acrylic resins in a solution of water-soluble cellulosic material. Kremer 87032.
- KLUCEL G: Hydroxy-propyl-cellulose. Kremer 63706
- Lascaux Hydroground 750 : nBuMA-MA. Copolymer Isobutyl methacrylate, Methacrylate dispersion Lascaux 2001. Kremer 81027
- TritonDF12: non-ionic surfactant. Lascaux 4252

Equipment:

Microscopy: Hirox KH 8700 with 2016Z lens (Hirox, Japan).

Fourier Transform InfraRed spectroscopy: FT-IR Focal plane array (FPA) imaging was performed on a Bruker Hyperion 3000/Tensor 27 infrared spectrometer with a germanium-attenuated total reflectance (ATR) crystal (20x objective A677-B10, crystal diameter = 250 µm). The spectral resolution achievable with the Cassegrain optics (NA 0.6) and the ATR Ge-crystal (Ge: nD 4.0) is between ~0.6 and 2.5 µm. The pixel resolution is 0.5 µm with the FPA detector made of 64x64 detector elements, covering an area of 32x32 µm (4 pixel per µm2). The 2D FTIR-FPA imaging was performed at 8 cm-1 spectral resolution and 64 scans (Spectral range: 4000-900cm-1).

Raman spectroscopy: Renishaw InVia (2007) system, 250 mm focal length, maximum resolution about 0.5-1.0 micrometer. Laser systems 785nm (Diode type), 633 nm (He-Ne-type and 514 nm (Ar-type). N-plan objectives on a Leica DM LM microscope.

Scanning electron microscopy: SEM-EDX: Zeiss EVO MA 10 SEM (2014) (W-cathode and variable pressure chamber) equipped with a Thermo NORAN System 7 for EDX measurements. Settings used for mapping were 20kV, 500pA, 512x384 pixel, 100 frames at 20 frames per second, (dwell time per spot 101µs) on carbon evaporation coated cross-sections.

GC-MS: The pyrolysis-TMAH-gas chromatography-mass spectrometry (Py-GC-MS) analyses were performed on a Thermo Quest GC-8000 equipped with a Supelco column Equity®-5, capillary GC column of 30m (I.D. 0.25mm, df 0.5) interfaced with a MS MD-800. See Van Keulen 2014.

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COMPARING THE EFFICACY OF FOUR METHODS OF PREPARING 3D-PRINTED POLYMER SURFACES TO TAKE PAINT AND THEIR EFFECT ON AN ACRYLIC PAINT LAYER

Abstract

This study assessed methods of processing the surfaces of Fused Deposition Modelled (3D printed) PLA and ABS polymers. The goal of processing these surfaces was to reduce the appearance of the corrugation inherent to these objects to create a surface upon which a paint layer could be applied. Reduction of corrugation and the addition paint was used to establish the suitability of FDM-printed PLA and ABS for use as infills in conserving low-fired ceramics. Two phases of testing were employed. Phase One compared how successful four methods of processing the sample surfaces with heat, abrasion, solvent, and filling were by using micro-photography, Gloss Meter readings, and a "Touch Test". Phase Two dealt with assessing the adhesion rates of a paint layer by administering an ASTM "Cross-cut Tape Test" and later painting samples to mimic low-fired ceramic objects. Heat processing was unsuccessful. However, the other three methods effectively reduced the appearance of the corrugation. The "Cross-cut Tape Test" showed that the solvent and abrasion methods had the highest rates of paint adhesion. Finally, it was concluded that the solvent method was to be recommended of the methods tested due to the ease of treatment and the high paint adhesion rates.

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Keywords:
3D-Printing; FDM; ceramic conservation; infills; paint adhesion; surface processing; PLA; ABS

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Introduction

This study focuses on the aesthetic characteristics of 3D-printed items, investigating methods of processing the surfaces of 3D-printed objects to establish their suitability for use as removable infills in low-fired ceramic objects. 3D printing is gaining recognition in the conservation world as advances in technology have created applications in recording, replicating, and conserving cultural heritage objects. Among other advantages, this technology can reduce the amount of handling of artefacts that is required during the conservation process, which reduces the risks posed to objects. However, as with any tool, there are issues with using 3D-printed items in conservation, such as their aesthetic qualities. Herein lies our discussion.

Fused Deposition Modelling (FDM) is a type of 3D printing that entails extruding heated polymer filaments through a small nozzle and building the item in three dimensions layer by layer. Each layer becomes fused to the one below it during the printing process. FDM can be an extremely precise and versatile method of reproducing intricate shapes, textures, and surface attributes of objects from 3D scans. It is also

very affordable when compared to other types of 3D printing, such as Stereolithography (SLA) or Selective Laser Sintering (SLS). However, because FDM items are created by layering polymer, the surface of any object produced by this method is inevitably corrugated to some degree. Although these corrugations are very small[1], they are visually distracting because of their regularity and manufactured appearance. When creating infills, it is often the goal to create a surface that is visually integrated with the entirety of the object. The application of paint facilitates further visual integration, though it is difficult to achieve on a corrugated surface. Thus, the appearance of this corrugated surface characteristic must be reduced to create a fully integrated infill. This study explores methods of reducing the visual impact of these surface corrugations and identifies any trends of higher/ lower paint adhesion rates due to those surface processing methods.

FDM was selected as the most accessible method of 3D printing for this study, though it was also necessary to limit the number of polymers used. For this reason, Polylactic Acid (PLA) and Acrylonitrile Butadiene Styrene (ABS) were selected. PLA and ABS are both chemically stable in that they do not off-gas Volatile Organic Compounds (VOCs)[2] in amounts that could negatively affect ceramics when in a regulated environment. They are also both inexpensive and readily available materials for FDM printing. The aim of experimentation in this study was to process the regular, manufactured "peaks and valleys" of the corrugated surface into one that was smooth enough to take a paint layer without those corrugations showing through. To process the surfaces of the 3D-printed PLA and ABS samples, four methods were trialled: (i) heat, (ii) abrasion, (iii) solvent, and (iv) filling.

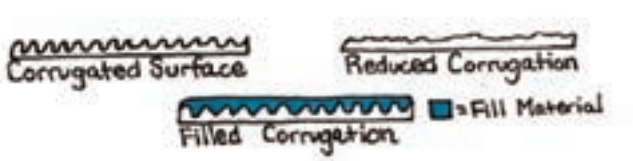

Figure 1: This schematic shows a cross section view (not to scale) of the undesirable corrugated surface with "peaks and valleys", the corrugation reduced by processing with heat, abrasion and solvent and the corrugation filled.

To evaluate the effectiveness of these methods, the samples' surfaces were compared against each other and assessed through microscopy, Gloss Meter readings, and a "Touch Test" Survey. Photomicrographs were modified post-production using ImageJ software to more clearly show the changes in the surface before and after surface processing. Gloss Meter readings were used to give an indication of how consistent the samples' surfaces were after processing. The Touch Test Survey gave a subjective impression of the smoothness of the surface. After samples were deemed consistently smooth, a layer of undiluted heavy-body acrylic emulsion paint[3] was applied. Once dry, the paint layer was scored and a "Cross-cut Tape Test"[4] was administered. This test revealed any trends of higher/lower paint adhesion rates across the processed samples when compared to unprocessed control samples. This gave an indication of how the processing methods affected the surface's ability to take a paint layer. To conclude evaluation, processed samples were "retouched" to establish whether these surface processing methods can be employed in normal working practice for conservators.

Review of relevant literature

Use of 3D printing in conservation

The technologies of 3D scanning and printing are beginning to be accepted and utilised in the conservation sector. In 2016-2017, two limestone busts damaged by ISIS in the ancient city of Palmyra were sent to the Instituto Superiore per La Conservazione ed Il Restauro in Rome for treatment using 3D scanning and printing. This proved to be a very precise and ethically conscious treatment in the view of the conservators and the governments involved. 3D printing and scanning have also been used to recreate or "re-restore" objects that were previously treated in less reversible ways. For example, JP Brown, an archaeological conservator at the Field Museum, used CT scanning and 3D modelling and printing to "re-restore" a skull from the Magdalenian era. From those scans, Brown was able to extract a digital model of the original bone fragments. Through digital manipulation, he repositioned the fragments into an alignment that better represents skulls of the era.

Authors Hae Soon Lee and Koang Chul Wi of the Department of Conservation Science at the National Museum of Korea in Seosan, South Korea wrote two articles on the use of 3D printing to restore previously damaged ceramic objects. These articles are linked

in that they both include an analysis of six potential fill materials, including PLA. After testing the materials' physical properties, it was Lee and Wi's conclusion that "there is no problem when [PLA is] applied as a ceramic restoration material." (Lee and Wi, 2015) Their conclusion was that using "digital technology-aided manufacturing of a restoration model requires less time and effort than handmade work and produces a more precise model. More importantly, this non-contact method reduces risks associated with handmade work." (Lee and Wi, 2015) However, Lee and Wi noted that there was work still to be performed after the 3D print was achieved. In particular, the print had to be shaped (minor adjustments), bonded to the object, and retouched.

The article titled *3D printing technology in the application of ceramic restoration and replication*, by Yun Yang of the Shanghai Museum Cultural Relics Research Laboratory, discusses the efficiency and convenience of using 3D printing technology in ceramic restoration. Yang highlights a single major advantage of this method, noting that "because the technology has the feature of non-contact scanning, it is a new method to protect high-valued pottery and porcelain for those who are engaged in restoration of cultural artifacts." (Yang, 2015) She continues to explain the practical process by which the 3D print was achieved. While Yang noted that the surface of the print was "relatively coarse and rough", she justified this method of printing because of its time and cost efficiency when compared to traditional methods. She concluded that "the rapidity and accuracy [of 3D printing] is incomparable with the traditional process." (Yang, 2015) Although Yang did not use FDM, instead choosing SLA, similar methods of fill production are applicable. In this study, Yang recognised the need to deal with the surface characteristics of the 3D-printed part to create a viable infill.

These three articles demonstrate the use of a range of materials, both 3D-printed substrates and retouching materials, which can produce a variety of textures and finishes. However, while these authors allude to the necessity of finishing the surfaces of the infills, they do not address in detail the processes by which the 3D-printed items were prepared to take paint or how those processes affected the infill. It is this gap in the research that this study aims to address for future conservators interested in working with 3D-printed infills.

Types of 3D scanning and printing and why FDM was chosen

3D scanning has already become a familiar process in museum collections. This process is being used to render objects for: digital cataloguing, creating replicas, and creating infills or replacement pieces for objects. 3D scanning offers the ability to create a digital rendering of an object that can be manipulated without physically handling the "real" object. There are two main modes of scanning: laser scanning and optical scanning. Both require minimal physical interaction with an object.

As discussed above, there are a number of 3D printing methods, as well as various materials available for use in printing. SLA and SLS printers are expensive when compared to FDM printers, thus, use of these printers would be less likely for conservators outside major institutions with sufficient funding.[5] FDM printing was chosen for this study because it is more accessible to a wider range of conservators being that both FDM printers and their filaments are very affordable. FDM is also comparatively easy to use, with less machine maintenance required and lower long- term costs for replacing printer parts. 3D scanning apps and equipment are also widely accessible and can then be used in conjunction with Computer Aided Design (CAD) software to produce a digital rendering of an infill. As such, conservators can produce these 3D-printed infills in-house with a working knowledge of CAD, or alternatively, have the desired pieces printed commercially should they not have the ability or desire to do it themselves.

Properties of the selected polymers

PLA and ABS polymers were chosen for testing not only because they are accessible and affordable but also because they do not off-gas VOCs in amounts that could be harmful to low-fired ceramics. (Billingham, 2018)[6] They also have very different physical characteristics, which makes them ideal for comparison. PLA is a biodegradable[7] plastic made from plant starches. It has a lower melting point than ABS and has a low shrinkage rate. ABS is not biodegradable[8] and has a higher melting point which would theoretically allow it to be abraded more easily and be heat treated with more control than PLA. The main physical difference that will affect experimentation on these polymers is the difference in their Glass Transition Temperature (Tg). ABS has a higher Tg than PLA: PLA's Tg is 65□C, whereas ABS's Tg is 105□C.

To effectively investigate whether the surface processing methods had any effect on paint adhesion, it was necessary to first establish what type of paint would adhere to both PLA and ABS regardless of the surface treatment. Acrylic paints are a popular choice among ceramic conservators when working on low-fired artifacts. In the case of acrylics, small-batch preliminary testing on PLA and ABS samples showed that it adhered to the plastic substrates, and thus testing with this paint continued.

Methodology

Objectives

- Test the effectiveness of heat, solvent, abrasion and filling as methods of processing FDM printed items to reduce the appearance of corrugation on the surface of the samples;
- Determine the effectiveness of the above methods in creating a consistently smooth surface onto which a paint layer could be applied. Assessed the surfaces using microscopy, Gloss Meter readings and a "Touch Test" Survey;
- Establish any trends of higher or lower paint adhesion rates resulting from the surface processing methods using a Cross-Cut Tape Test.
- Demonstrate that the processed samples can be retouched using normal working practices.

Execution of the above objectives required two phases of experimentation. Phase One consisted of processing the sample surfaces, while Phase Two identified which of the smooth processed samples from Phase One exhibited the best properties for adhesion of an acrylic paint layer to the surfaces and demonstrated that "normal" retouching methods can be used on these surfaces to create visually integrated infills.

Acceptable surfaces and samples

Definition of a "smooth" or "acceptable" surface

For the purpose of this study, the definition of a "smooth" or "acceptable" surface was one in which the corrugation was not distinguishable by touch and was smooth enough that the corrugation was not visually intrusive through a 0.5mm paint layer.

Samples

The experiment samples of both PLA and ABS were in an opaque white coloured polymer filament.[9] Though the surfaces of most infills would have some curvature, the samples used here were flat to ensure ease, accuracy, and uniformity of both the surface processing and paint layer application. Depending on the scale, FDM printed items can be hollow with an internal support structure.[10] These samples were large enough to necessitate being hollow, with internal honeycomb supports. Some of the samples used in the final experiments were also "open systems", meaning that one sidewall of the sample was omitted, and the interior was exposed, which proved to be an important characteristic for heat processing.

Experimental protocols

Phase one: surface processing

Heat

The goal of this processing method was to apply enough heat to allow the corrugations to become fused. A hot-air gun was chosen as it easily achieves high temperatures while being a more controllable heat source than a flame. During preliminary testing, it became apparent that merely heating the samples' surfaces would be insufficient to fuse the layers. In this instance, the sample was a "closed-system."[11] Warping and bubbling of the sample occurred on multiple sides. This indicated that the air inherently trapped inside the "closed-system" sample expanded when heat was applied with enough pressure to warp the sample. It was at this point that it became evident that if heat treating the samples was to be successful, an "open-system" model would be needed. To distribute the heat evenly, the sample was wrapped in a sheet of aluminium foil and a paint scraper was used to mechanically fuse the corrugations when the sample surface was warm enough to be pliable. The samples were left to cool completely to reduce the likelihood that the sample would warp should a second application of heat be necessary. Finally, the above steps were repeated in a second or third heat treatment. After the sample had completely cooled, the aluminium foil could be removed. The time, temperature, and distance of the heat source from the sample surface were regulated.

Abrasion

Abrading the surfaces of infills is common practice in ceramic conservation. Abrasion leaves marks or scratches (often microscopic) behind on surfaces. This may be advantageous in this study, as the scratches provide increased surface area for the adhesion of paint.

Abrasion was tested with P240 waterproof "Wet and Dry" Emery Paper[12] to establish if this sufficiently smoothed the samples' surfaces. Water was used as a lubricant during abrasion. Although it successfully

smoothed the corrugation, the emery paper left the sample surface somewhat stained, however, this side-effect was deemed of little consequence. It became apparent during preliminary testing that the time and direction of abrasion would have to be standardised for this experiment. The face of the sample being abraded was placed on the abrasive surface and abraded by hand using water as a lubricant. In an effort to evenly abrade the face of each sample, and create uniformity across the group of samples, the direction and time of abrasion were regulated. The sheet of abrasive paper was also changed to a fresh, unused piece for each round of abrasion.

The samples were inspected and assessed by touch after each round of abrasion to discern the extent to which the corrugation had been smoothed. They underwent as many rounds as necessary to create an "acceptably smooth" surface. Time taken and amount of water (measured in ml) used to reach that point were recorded.

Solvent

Use of solvent on polymers is also commonplace in conservation. In this case, the samples were processed using acetone as a solvent. While PLA and ABS swell to varying degrees when treated with acetone, its effect on each is enough to make the surfaces mobile.

Multiple methods of applying solvent, with and without the application of pressure or mechanical action, were trialled for this experiment.[13] It quickly became apparent that a certain amount of mechanical action would be required to smooth and fuse the corrugations while the polymer was swollen. A cotton swab proved an adequate tool to smooth the corrugations. Acetone was applied to the face of the samples via cotton swabs. The swabs were loaded with 0.5ml of solvent. The samples were then swabbed perpendicular to the direction of corrugation or in a circular motion until the sample was "smooth". The amount of solvent used and time taken to process each sample were recorded.

Filling

While making infills, some secondary filling is often required to prepare the surface to take a paint layer. In this case, the FDM printed item would be the infill, while the surface processing method would be tantamount to secondary filling (see Figure 1). To fill the corrugation on the samples' surfaces, a mixture of Paraloid™ B72 and Glass Micro-balloons was used. This material was chosen to secondary fill because it is a common fill material in ceramic conservation (Buys and Oakley, 2014), and because it is dissolvable in acetone. During preliminary testing, the mix of the fill material was adjusted with acetone and Industrial Methylated Spirit (IMS) so that it was liquid enough to be easily applied to the samples' surface. The Paraloid™ B72 and Glass Micro-balloon mix was 26.6% Paraloid™ B72 adhesive, 26.6% Glass Micro-balloons, 23.3% additional acetone, and 23.3% IMS. To apply the fill material enough of the Paraloid™ B72 and Glass Micro-balloon mix to reasonably assume that the corrugation lines will be filled was applied to the sample using a metal micro-spatula. Multiple applications may have been necessary. Where this was the case, a second application was performed after the first layer of fill material was completely dry.

Analytical protocols

Phase two: paint adhesion testing

To test how the surface processing methods from *Phase One* affected the adhesion of the paint, a Cross-cut Tape Test was administered. This test is standardised by The America Society for Testing and Materials (ASTM, standard no. D3359) for rating adhesion of a coating to a substrate. It rates adhesion by testing the coating's resistance to separation from the substrate.[14] Processed samples were painted and compared to painted unprocessed/corrugated control samples. Comparing processed samples to the control samples during the Cross-cut Tape Test showed if and how much each processing method affected the paint adhesion. To administer the test, a 0.5mm layer of heavy-body acrylic emulsion paint was applied evenly to the samples using a draw-down bar applicator. Once the applied paint layer had dried completely, the samples' surfaces were "cross-cut" in the manner dictated by ASTM D3359. A strip of pressure-sensitive

Classification given by ASTM	Percentage of Paint Removed
5B	0% (none) removal
4B	Less than 5% removal
3B	5-15% removal
2B	15-35% removal
1B	35-65% removal
0B	Greater than 65% removal (failure)

Table 1: The ASTM D3359 Classifications.

Figure 2: The image on the left shows the microscopy setup and angles in the light. The image on the right shows how the samples were photographed in the darkroom. Photo: Amanda Berg.

tape was then applied over the scored area.[15] The tape was then quickly removed, and any removal of the paint layer via the tape was evaluated according to the standards provided by ASTM (the table below provides the classification and percentage of paint removed).

The results of the Cross-cut Tape Test were collated, and the processed samples' results were compared to both the other processing methods' samples and the control samples. This revealed whether the surface processing had an effect on the paint adhesion as compared to the controls of each polymer, and which of the methods showed the best rates of paint adhesion, if any. The results are presented here in Table 2.

Evaluation of samples

To evaluate the smoothness and consistency of the sample surfaces, three methods were employed: (i) photo-microscopy, (ii) Gloss Meter readings, and (iii) a "Touch Test" Survey.

The first method of evaluation was via microscopy under raking light. The samples were photographed under 45x magnification. Standardisation of the photomicrographs was ensured for all samples by using the setup shown in Figure 2.

Photomicrographs of the samples' surfaces were taken both before and after surface processing took place. These images are presented (Figures 6-9) both in their original format and in a modified format to make the contrast between before and after processing more apparent. As stated, the images were modified using ImageJ software.[16]

The second method of assessment utilised the Gloss Meter. The Gloss Meter was used to give an objective indication of the consistency with which the processing methods altered the surfaces of the samples. Initial gloss readings were taken of each sample before the surface processing occurred. After processing, four readings (one in each quadrant, as shown in Figure 3) were taken on each sample's surface. The gloss readings of the quadrants were then compared, and if they fell within five Gloss Units (GU) of each other, the sample was deemed consistent.

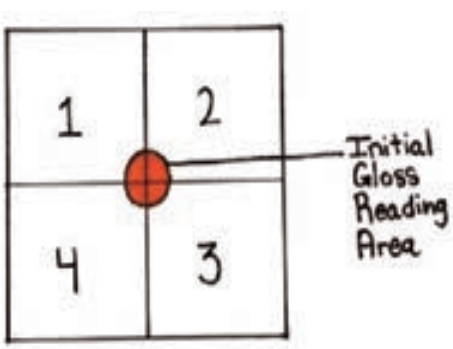

Figure 3: This schematic shows both the area where initial gloss readings were taken on the unprocessed sample, as well as the quadrants measured post-processing.

The third method of assessing the processed samples' surfaces was via the "Touch Test" Survey. Half of the successfully processed samples were selected at random to take part in the survey, during which twenty participants were asked to classify the smoothness of the processed samples on a pass or fail basis based on reference samples which were provided. When the results were collated, any sample for which 50% or more of the participants marked "pass" was deemed smooth.

Analysis and discussion of results

Phase one results

Experimentation began by first taking photomicrographs of the surface of each of the samples as described earlier. These images provided a basis for comparison between the surfaces before and after processing. Initial Gloss Meter readings were also taken from the centre of each sample before processing.

Heat

In Phase One, testing revealed that treating the samples with heat using the aforementioned protocol was unsuccessful. The presence of a corrugated and warped surface with aluminium foil still attached precluded samples treated by this method from continued testing (see Figure 4). While the idea of altering the surface with heat is sound in theory, it was very impractical. Eliminating heat as a surface processing method was advantageous because this method required an open-system sample. In practice, attempting to use an open-ended infill could be difficult and unfeasible.

Figure 4: This image shows the PLA samples processed by heat. Photo: Amanda Berg.

Abrasion

Abrasion yielded the smoothest samples when they were assessed by touch. This was the only surface processing method for which samples unanimously passed in the Touch Test Survey. While the samples processed with abrasion were the smoothest to the touch, the corrugation on the surface was still visible to the naked eye. This visibility was due mainly to the staining that occurred during abrasion. Particles of the abrasive paper became lodged in the sample surfaces. This produced a "visually corrugated" surface even though it was smooth to the touch. The staining was of little consequence in this instance, as it was not visible through the paint layer that was later applied. However, when paint was applied, the corrugation became visible again to the naked eye. This suggests that even though the samples felt smooth to the touch, more abrasion would have been required to adequately prepare the surface for a paint layer. The abraded samples were the only samples on which the corrugation was visible after paint was applied.

The average time and amount of water used on the PLA samples to create a smooth surface was higher than that of the ABS samples. This affirmed that the Tg of the polymers did in fact have a relatively large impact on how efficiently they could be abraded. While abrasion effectively smoothed the sample surfaces and

Figure 5: This image shows a PLA sample processed by abrasion with paint applied and the corrugation visible through the paint. Photo: Amanda Berg.

the paint adhesion rates were high, conservators would have to abrade the polymer past the point where the corrugation is no longer palpable, should they wish to use this method to prepare an FDM-printed infill.

Solvent

Solvent was very effective in reducing the corrugation on both polymers. In general, less time and solvent were required to produce an acceptable surface on the ABS samples. When a paint layer was applied, the corrugation was not visible on any of the solvent processed samples. The only sample to fail the Touch Test Survey was a PLA sample processed with solvent. It presumably failed not because the corrugation was still present, but because the solvent process left the surface with bumps and accretions where the polymer had been moved across the surface during processing. These irregularities were noted on all the samples that were processed with acetone. With paint applied, the surface irregularities were not visible, and in fact, the newly textured surface aided in mimicking the texture of the archaeological vessel. The ABS samples processed with acetone also showed high paint adhesion rates. Using acetone on PLA was just as effective, however, the processing required more time and solvent. Thus, for ease of treatment, ABS may be a better choice. The solvent processing method performed the best during all methods of assessment, including the retouching portion, where it easily mimicked the surface texture of a low-fired artefact.

Filling

Filling as a processing method was very successful in reducing the appearance of the corrugation. Though filling produced a regular and smooth surface, the Paraloid□ B72 and Glass Micro-balloons mixture gave the samples a unique texture that was unlike the other surfaces produced in this study. When paint was applied to these samples, they exhibited different visual properties than the other processed samples and the paint also appeared to be more matte. In many cases, the texture inherent to the Paraloid™ B72 and Glass Micro-balloons could be advantageous to conservators. The ease with which the surface of a low-fired object could be mimicked on the fill material is a significant advantage in everyday practice. The fill material would also be relatively easy to evenly apply to a complex-shaped infill.

Photo-microscopy and imageJ results

One sample processed by each of the four methods was selected for presentation here. These samples' images are given in both their original format and modified with ImageJ software as described previously. Modification with ImageJ software enhanced the visibility of the altered surfaces. In the following figures, the top set of images is in the original format, while the bottom set is modified. The images on the left show the samples before processing and those on the right show them post-processing.

Gloss meter readings

The Gloss Meter was used to give an objective indication of how consistent the processing methods were in the alteration of the samples' surfaces. The difference in the Gloss Meter readings before and after processing show that the surfaces were significantly affected by the surface processing. Gloss readings taken from all four quadrants of every sample after processing indicated that all the samples were consistently processed. All readings taken were within five GU of each other across the sample surface (circled in red on the sample graph in Figure 10). This indicates that all samples were consistent within the prescribed definition of consistency. Interestingly, even the samples processed by heat were "consistent" when

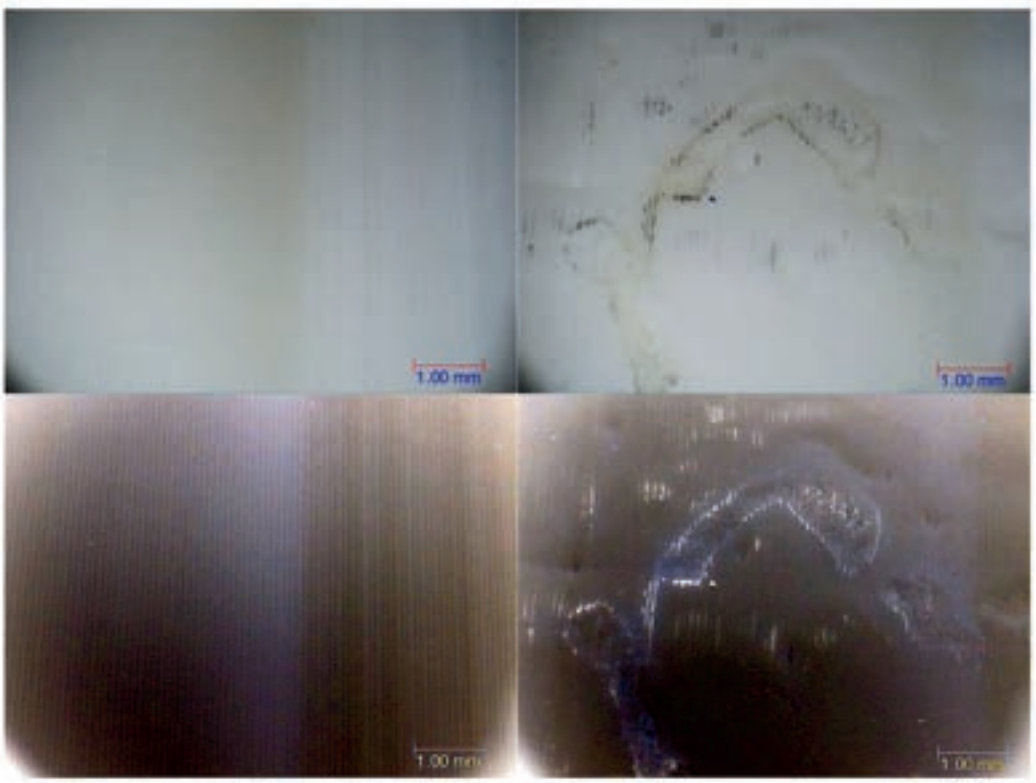

Figure 6: Photomicrograph showing an ABS sample processed by heat. Some discolouration and warping can be seen. Photo: Amanda Berg.

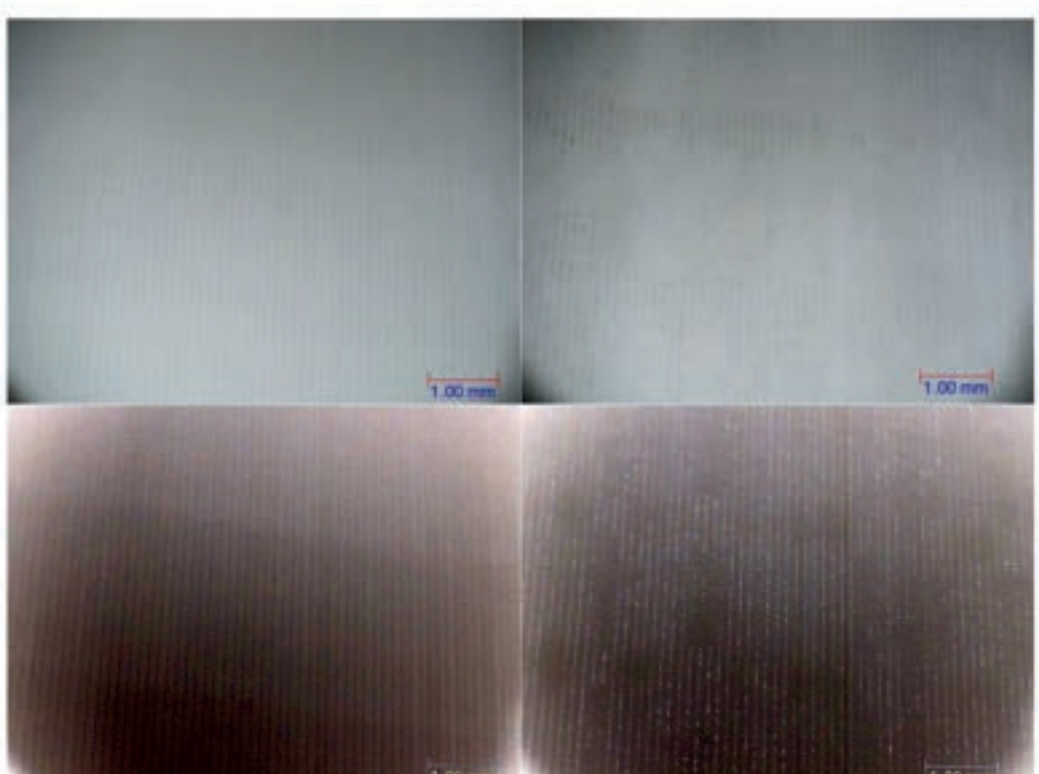

Figure 7: Photomicrograph showing a PLA sample processed by abrasion. The staining can be seen. Photo: Amanda Berg.

Figure 8: Photomicrograph showing an ABS sample processed by solvent. Photo: Amanda Berg

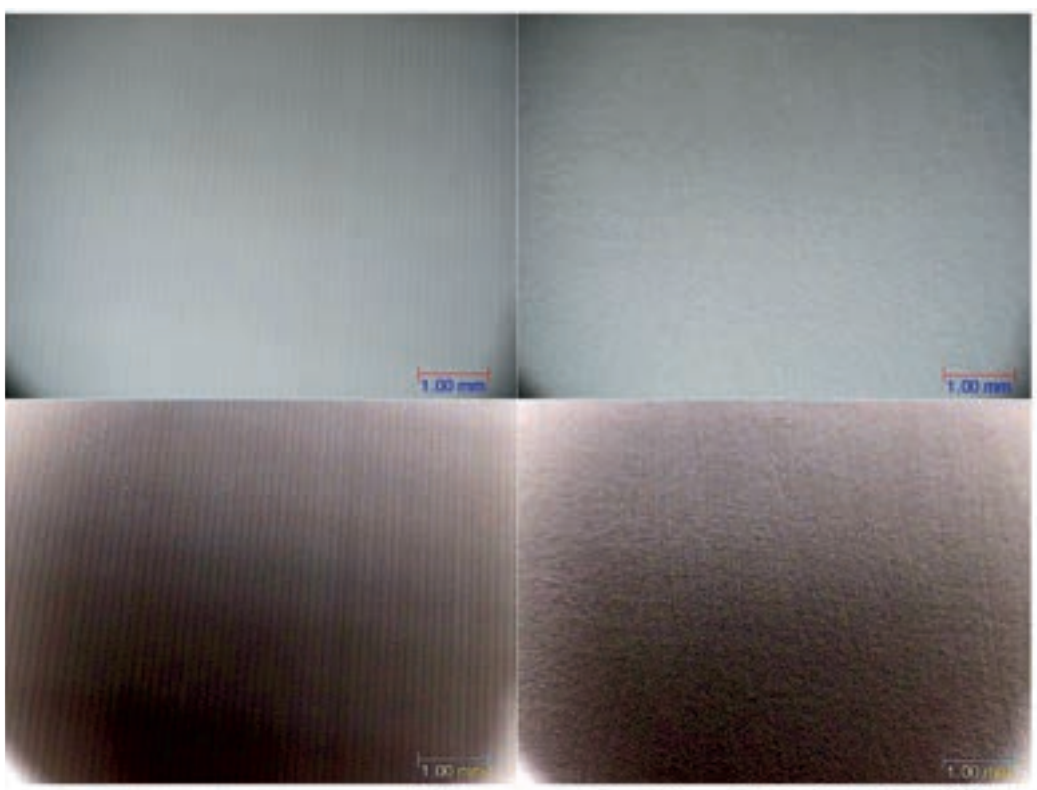

Figure 9: Photomicrograph showing a PLA sample processed by filling. Photo: Amanda Berg.

gloss readings were taken. This indicates that although the heat method was unsuccessful in removing the corrugation, the polymer surfaces were treated evenly with the application of heat. All samples being consistent within the definition may be an indication that the Gloss Meter was not the best suited instrument to corroborate the results of the processing that were observed.

Touch test survey results

During the touch test, all samples ranked as “Pass” except one. The sample that failed the touch test was a PLA sample processed with solvent.

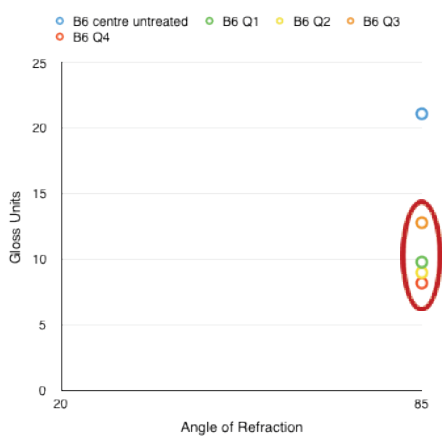

Figure 10: ABS Sample processed by solvent.

Samples	Classification
A1	2B (15-35%)
A2	3B (5-15%)
A4 (control)	0B (> 65%)
A5	5B (0%)
A6	5B (0%)
A8 (control)	0B (> 65%)
A10	1B (35-65%)
A11	0B (> 65%)
A12 (control)	0B (> 65%)
A16 (control)	0B (> 65%)
B1	5B (0%)
B2	3B (5-15%)
B4 (control)	4B (< 5%)
B6	4B (< 5%)
B7	4B (< 5%)
B8 (control)	4B (< 5%)
B9	0B (> 65%)
B10	2B (15-35%)
B12 (control)	4B (< 5%)
B16 (control)	4B (< 5%)

Table 2: Results of the Cross-cut Tape Test.

Phase two results

Phase Two of testing included the Cross-cut Tape Test. The results of the Cross-cut Tape Test are presented here in Table 2. The “classification” refers to that given by ASTM. The corresponding percentages of paint removal are also listed here.

PLA control samples showed a very low paint adhesion rate, with all the control samples classified 0B (more than 65% of paint removed). The samples processed with abrasion and solvent showed much higher rates of paint adhesion. None of the samples processed with abrasion or solvent were classified below 2B (15-35% of paint removed). The solvent samples showed no paint removal, making this the most effective method to ensure paint adhesion. ABS control samples showed a much higher rate of paint adhesion than the PLA, with all of the control samples classified 4B (less than 5% of paint removed). Again, samples processed by abrasion and solvent showed high rates of paint adhesion, with none scoring below a 3B (5-15% of paint removed).

The high rates of paint adhesion on the abrasion and solvent samples among both the polymers indicated that a certain degree of surface “roughness” is advantageous in this instance. This is probably because the roughness creates more surface area to which the paint can adhere. These microscopic irregularities in the surface give the paint “keys” to lock and hold on to.

Interestingly, the samples that were processed by filling showed the lowest paint adhesion rates of all the successfully processed samples. On both the PLA and ABS, none of the filled samples were classified above a 2B (15-35% of paint removed). Two of the samples were classified 0B (more than 65% removal). It was observed, however, that it was not the paint that did

not adhere to the fill material, but rather that the fill material itself was removed from the substrate with the tape. This suggests that it was not a fault of the paint layer that led to poor adhesion, but instead that the fill material's bond with the polymer substrate was very weak. Although the Paraloid™ B72 and Glass Micro-balloons showed poor rates of adhesion to the polymer surface, it should not be completely discounted as a method of preparing FDM-printed infills to take paint. It is unlikely that a conservator would forcefully attempt to remove the paint or secondary fill material as was performed in this study.

The Cross-cut Tape Test was an effective method of establishing higher/lower adhesion rates of the acrylic paint layer, while also giving an indication of how retouching on these polymers might be affected or changed in the future. The high rates of adhesion on the solvent and abrasion samples could indicate the longevity of retouching on infills processed by those methods. Conversely, the low adhesion rate on the filled samples might indicate that retouching could be removed and reapplied on infills with Paraloid™ B72 and Glass Micro-balloons secondary filling.

Retouching to mimic low-fired and archaeological ceramic objects

The final stage of testing consisted of retouching the remaining unpainted samples to match three archaeological or low-fired ceramic objects. One sample of each polymer processed by the three successful methods was painted to mimic the objects. To retouch, diluted heavy body acrylics mixed with acrylic matte medium were applied with a paintbrush, as in normal practice. One of the resulting "infill" samples is shown in Figure 11. This portion of testing was undertaken to show that normal retouching methods could be used successfully on these processed polymer surfaces.

Figure 11: This object was provided by the Novium Museum in Chichester, U.K. and is from the St. Pancras Roman Cemetery. The two samples that were retouched to mimic the object were processed by solvent. The PLA (left) had a printing flaw that resulted in the two visible horizontal lines on the sample in the image. Photo: Amanda Berg.

Conclusion

Although 3D printing has its place in conservation, there is still a considerable amount of space for development of both the technology and its application in this field. Currently, it could be argued that 3D printing infills would be most suited for large areas of loss, such as large rims and body sherds. It is particularly useful now as a way of "filling", or recreating, entire sections of an object. As technology advances, this will likely change. In the future, conservators may be able to print very small and delicate removable infills which are light-weight, robust, and easily reproducible. The application of 3D scanning and printing could lead the way for much more conscientious and minimally interventive treatment methods for museum objects going forward.

The aim of this investigation was to identify successful methods of processing FDM-printed polymer surfaces to reduce the appearance of the inherent corrugation and establish trends of higher/lower adhesion rates of an acrylic paint layer resulting from those processes. Should current conservators be interested in using an FDM-printed infill in practice, it is recommended that they print in ABS and prepare the surface for paint with acetone. This surface processing method was the most effective in removing the corrugation in the shortest span of time while using the least solvent. Importantly, in practice, solvent treatment could be performed with ease on almost any shape of infill due to the adaptability of solvent application via swab. While abraded samples were successfully retouched to mimic the surface of an artefact, covering the remaining corrugation with thin washes of paint was more difficult than on the solvent samples. Surface processing by abrasion could also pose a problem if the shape of the infill printed was too irregular to be evenly abraded. In this instance, solvent processing has a clear advantage over abrasion. Secondary filling is still a viable option for surface processing, however, in the future the mixture used could be adjusted by increasing the amount of adhesive in the fill material, thereby strengthening the bond and compensating for the poor adhesion observed in this study.

Before the use of FDM-printed infills can be assimilated into normal conservation practices, further study is required. Some areas for further research and testing are: (i) the long-term structural stability of FDM-printed objects, (ii) whether a flame can be used to prepare the polymer surfaces for paint, (iii) whether other types of paint show better adhesion rates than an acrylic emulsion, (iv) whether other abrasives would be more suited to smoothing these infills, and (v) whether other types of printed polymers could be more advantageous than ABS or PLA for conservation.

Endnotes

1. The peaks of the corrugations are typically 0.2-0.4 mm. (D. LiPuma, 2018, FDM Printing, Informational Interview)

2. Any polymer that would off-gas large amounts of VOCs like acetic and formic acids, hydrogen sulphide, sulphur dioxide, formaldehyde, or acetaldehyde could potentially cause damage if absorbed into the porous (low-fired) clay body. [P. Art, 2018, 'Philadelphia Museum of Art - Research: Conservation.', Philamuseum.org, (Web).]

3. Acrylics were selected because they are the most common type of paint used for retouching in the context of low-fired ceramic objects. [S. Buys and V. Oakley, 2014, 'Conservation and Restoration of Ceramics.' (Hoboken: Routledge Taylor and Francis).]

4. Standardised by ASTM (D3359-17 Method B)

5. Though SLA is quickly becoming more affordable, and this method produces items with slightly smoother surfaces than FDM, objects printed with SLA would still need surface processing because they are produced with a similar additive layering process. So, although the surface corrugations might be smaller, this study remains relevant to finishing the surfaces of objects printed with SLA.

6. This statement is also supported by the Getty Conservation Institute, and by the British Museum's Oddy Tested Materials Database. [C. Grzywacz, 2006, 'Monitoring for gaseous pollutants in museum environments.', (Los Angeles, Calif.: Getty Conservation Institute).] [The British Museum, 2018, 'Selection of Materials for the Storage or Display of Museum objects (Oddy test)', britishmuseum.org, (Web).]

7. In this instance, biodegradable does not imply that it is unstable, it simply means that it is eco-friendly and, given enough time or the right conditions (not museum conditions), it will break down. (N. Billingham, PhD, 2018, Questions about PLA and ABS, Informational Interview).

8. This may make it more suitable for longer-term infills. ABS was developed in 1948. Natural aging has shown that ABS is stable in a regulated environment for decades. [ScienceDirect Topics, 2018, 'Acrylonitrile Butadiene Styrene - an overview', Sciencedirect.com, (Web).]

9. Filament spools of both polymers are available for order in a variety of colours, although the available colours would not be able to be printed with enough nuance to be visually integrated with a ceramic object.

10. FDM printing an object does not automatically necessitate that the item be hollow with internal supports. In general, the specifications of a print can be selected depending on its intended use. The option to set any necessary specifications for printing is part of what makes this technology so versatile and useful in the context of conservation. In this experiment, roughly 25% of the internal volume was occupied by the supports.

11. Closed-system meaning that the interior was completely sealed.

12. This is Klingspor® PS 8A waterproof Auto-Paper, made of silicon carbide grit.

13. Solvent submersion and fumes were both trialed during preliminary testing. These methods resulted in warping and localized slumping, especially in the internal supports. Because the structural integrity was affected, further testing with these methods was discontinued.

14. ASTM D3359-17 Method B standard was used. Method B is deemed more suitable for laboratory tests. [ASTM, 2010, 'Standard Test Methods for Measuring Adhesion by Tape Test', section 1.2, ASTM, (Web)]

15. The tape used is also dictated by ASTM D3359; for this study, brown, semi-transparent, wide parcel tape was used. (ASTM, 2010, cited in note 12 above, sections 5.3, 12.7).

16. The exact modifications applied to the images are as follows: Edit□ Invert, Process□ Sharpen, Process□ Enhance Contrast (enter 0.5%) □ OK

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