THE CONSOLIDATION OF MUD-SILK AND PAINTED THREE-DIMENSIONAL TEXTILES

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Submitted in partial fulfilment of the requirements of the Degree of Master of Philosophy in Textile Conservation in the School of Culture and Creative Arts, University of Glasgow, 22 August 2013.

ABSTRACT

Recent research highlighted the existence and significance of a unique Chinese textile, mud-silk, which has a glossy applied surface finish. A mud-silk jacket donated to the Royal BC Museum had an unusual flaking condition, sparking this investigation into its consolidation, and that of three-dimensional textiles with an applied surface film or paint. The research aimed to find consolidation treatments that would stabilise the flaking surface film without compromising the flexibility of the textile, maintaining its visual integrity and historical silhouette. Consolidants tested were isinglass, Aquazol® 200 and funori, with emphasis being placed on the application techniques and solution parameters, namely concentration and volatility. An aerosol spray technique was developed that, while having limitations, allowed good control of consolidant application. Treatments were tested for their consolidation effectiveness on painted silk specimens, then for their effect on the flexibility of un-used mud-silk dating from the 1950s. Flexibility tests were undertaken using instrumental and sensory methods. Results showed that overall, funori 0.1% affected the flexibility of mud-silk the least, and isinglass 3% the most. There was also found to be a complex relationship among solution properties such as volatility, concentration and viscosity, which impacted textile flexibility, warranting further research in this area.

ACKNOWLEDGEMENTS

This dissertation would not have been possible without the inspiration and support given by staff at the Royal BC Museum (RBCM). In particular, Kjerstin Mackie, one of the author's supervisors whilst undertaking a textile conservation placement at the RBCM, encouraged further research to be undertaken. Academic support and encouragement was also provided by Dr Tzu-I Chung (Curator, Chinese History), Dr Lorne Hammond (Curator, History) and Charlene Gregg (Collections Manager, Human History).

Support was also provided by Professor Elizabeth Tanner (Professor of Biomedical Engineering, University of Glasgow), who facilitated the construction of the fixed-angle flexometer. While the apparatus was not utilised, the author is grateful for the contribution to the project.

Special thanks also to the author's dissertation supervisor Karen Thompson, who was instrumental in the development of methodologies and key concepts regarding painted textile consolidation.

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INTRODUCTION

Background

In 2012, the author carried out an investigation on a collection of 22 mud-silk garments, dated to between 1890 and 1920, at the Royal British Columbia Museum (RBCM), Victoria, British Columbia, Canada. Most of the garments had been donated to the Museum in 2004 after they had been found among the possessions of deceased individuals in Victoria's Chinese community, and comprised Chinese-style trousers, waistcoats and jackets. Following research conducted by Lin, Lillethun and Ordoñez identifying mud-silk and highlighting its cultural and social significance, the RBCM realised that this collection of garments may have been more significant than they first determined, and requested the author to establish if the collection could be defined as mud-silk, making it a significant indicator of local social history.[1] Lin et al. described mud-silk as a bi-coloured fabric with a glossy black obverse and matte orange-brown reverse, a major identifying factor for the textile.[2] The author's investigation thus confirmed that the Chinese textiles were indeed mud-silk, and provided information regarding the fibre content, quality and construction of the garments, as well as commenting on potential preventive and interventive conservation paths.

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[1] Shu Hwa Lin, Abby Lillethun, and Margaret T. Ordoñez, "Identification, Characterization, and Care of Mud-Coated Silks from Southeast China and Southeast Asia," *AIC Textile Specialty Group Postprints* 19(2009).

[2] Lin, Lillethun, and Ordoñez, p103.

While examining the garments, a number of condition aspects were observed that indicated past storage in cramped, damp conditions before being accessioned by the Museum. In particular, most garments had randomly patterned wrinkling or sharp creases, indicating they had been stored crumpled or folded and compressed. A few garments also showed damage from past insect activity and one or two moth casings, as well as inactive mould spores, indicating a damp storage environment. One particular jacket also had an unusual flaking problem, resulting in tiny black fragments detaching from the textile and shedding whenever it was handled. Initially it was unknown whether the shedding particles were tiny fragments of black-dyed fibre or flakes from some kind of surface finish, and microscopic examination indicated the latter option was most likely. While the problem was not prevalent, with only one out of nine examined objects affected, it severely impacted the preservation of and ability to handle the specific jacket in turn affecting the research and display potential of the object, as the ability to move and examine it without causing damage was limited. The flaking condition can thus be considered a conservation issue requiring interventive treatment to allow safe handling and display. It is unknown whether this condition is present in mud-silk in other collections, however as mud-silk becomes more widely known of and identified, it is possible that other examples of the flaking condition will become known. It was therefore identified that research into the interventive treatment of flaky mud-silk would be useful anticipatory work, providing a practical starting point for conservators wishing to make flaky mud-silk objects safe for handling and display.

The conservation of flaky mud-silk was the premise for this work, directing the research route; however, the problem investigated also had wider applications. It was identified that due to mud-silk's unusual glossy obverse surface, which was not derived from mechanical finishing processes, its structure was similar to fine painted textiles that are sometimes used in the construction of garments (e.g., the painted silk dress conserved by Haladane).[3] Painted textiles can also exhibit flaking, the stabilisation of which usually requires a consolidation treatment, yet a search of painted textile conservation literature revealed that very few examples of painted garment consolidation exist. It became clear that the techniques reported for the consolidation of heavier two-dimensional painted textiles were not necessarily appropriate starting points for conservators wishing to consolidate lighter three-dimensional painted garments. This is because of the risk of stiffening textiles with the application of a consolidant, and because of the emphasis on drape and silhouette in historical garments this risk is more pronounced when consolidating garments. It was therefore identified that this investigation could provide information regarding the consolidation of painted three-dimensional textiles, an area with relatively little published work.

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[3] Elizabeth-Anne Haldane, "Encounters with Paper Conservation: The Treatment of a Chinese Painted Silk Dress," *V&A Conservation Journal*, no. 49 (2005), http://www.vam.ac.uk/content/journals/conservation-journal/issue-49/encounters-with-paper-conservation-the-treatment-of-a-chinese-painted-silk-dress/.

Overview

The following report provides the reader with background knowledge of the production and significance of mud-silk, building a case for its conservation and developing the idea that the treatment of flaky mud-silk should be approached in the same way as that of painted textiles. A review of the literature on the consolidation of canvas paintings and painted textiles discusses the conflicting issues with achieving consolidation while maintaining a textile's flexibility, and gives an overview of consolidants and practices that are commonly employed. The review also discusses authors' assertions that manipulating consolidant properties and application technique can allow the effect of a consolidant on an object to be controlled. An overview of textile science techniques for evaluating the flexibility of fabrics provides the background and justification for their use in the investigation, arguing that a thorough evaluation of the effect of treatments tested was necessary. Methods and results are presented, and findings are discussed in relation to the aims in the following section.

Research questions, aims and objectives

Research questions

The investigation had two overarching research questions, derived from the flaking condition observed in the RBCM mud-silk jacket, and the wider application of consolidating three-dimensional painted textiles:

- 'How can mud-silk with a flaking surface finish be stabilised to allow safe handling and display?'

- 'How can fine, three-dimensional textiles with an applied surface film (such as paint or a finish) be consolidated without perceivably altering their flexibility and form?'

Aims and objectives

The aims and objectives were developed based on the author's experience with mud-silk and information present in the paintings and painted textile literature. Each aim is presented with its objectives bullet-pointed below.

Aim 1:

Evaluate consolidants commonly used in paintings and textile conservation for their ability to consolidate flaky mud-silk or other textiles with an unstable applied surface film (such as paint or a finish) without perceivably altering their flexibility, by:

a. Finding a selection of consolidation treatments that successfully consolidate artificially flaked mud-silk, based on paintings and painted textile conservation literature.

b. Instrumentally measuring the flexibility of mud-silk following successful consolidation treatments, and evaluating if it is any different to non-treated mud-silk.

c. Undertaking sensory evaluation on the flexibility of mud-silk following successful consolidation treatments, and discerning if it is perceivably different to non-treated mud-silk.

Aim 2:

Explore theories discussed in conservation literature asserting that manipulating consolidant solution properties can control its penetration into the paint or surface film and textile of paintings and painted textiles, and by extension its effect on the textile's flexibility, by:

a. Comparing a selection of consolidant solutions made to different concentrations and with different solvents for their effect on the flexibility of mud-silk, through instrumental and sensory evaluation methods.

Aim 3:

Develop and explore the use of an aerosol spraying technique for consolidant application to textiles, and discuss the merits and drawbacks of the technique, by:

a. Identifying variables contributing to consolidation with an aerosol system.

b. Comparing the effects of variable parameters on consolidation, and identifying the most appropriate parameters for each variable.

This investigation did not propose to explore potential causes of the mud-silk flaking condition. It was proposed that any information revealed through the development of artificially flaked mud-silk (Aim 1, Objective a) would be incidental, and that the focus of this investigation was to find a practical conservation solution to the flaking condition.

CHAPTER 1 MUD-SILK

1.1 Introduction

In order to sufficiently understand the conservation needs of mud-silk, background knowledge of its physical nature, manufacture and social importance is necessary. Understanding the significance of mud-silk also provides a rationale for why it is important to conserve historical examples, and highlights the research and display potential of mud-silk in historical collections. This chapter therefore familiarises the reader with mud-silk as a material, discussing its historical and current significance in China, Southeast Asia and locations that had an influx of Chinese immigrants at the turn of the 20th Century. The chapter goes on to discuss the current knowledge regarding the conservation of mud-silk, the relationship between mud-silk's unique structure and the flaking condition noted in the RBCM jacket, and how knowledge of the structure can aid in treating the flaking condition. This lays the foundation for the conservation treatment that was investigated in this project.

1.2 What is mud-silk?

Mud-silk is a little-known textile produced in Southeast China and other areas of Southeast Asia, with a characteristic glossy black face and an orange-brown back.[4] After dyeing with a tannin-rich plant root extract,[5] which imparts the orange-brown colour, the silk face is spread with iron-rich river mud and baked in the sun for several days.[6,7,8] The mud is then washed off, revealing a glossy black surface finish.[9] It appears that the iron in the mud reacts with the tannins in the dye to produce a chemical complex that makes the silk surface appear black instead of orange-brown.[10] Various sources assert how the glossy finish is achieved, with methods ranging from applying the juice of unripe persimmons, to sprinkling with anthracite coal dust or a performing a final dipping in the root extract dye, however there is no concrete information available.[11,12,13]

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4 Lin, Lillethun, and Ordoñez, pp102-103.

5 Sources refer to the use of 'dye yam' or the ju-liang root (*Dioscorea rhipogonioides*, synonym for *Dioscorea cirrhosa*).

6 Ximin Han, "Silk Fabric Gets Better with Age," *Shenzhen Daily*, May 17 2007, http://paper.sznews.com/szdaily/20070517/ca22665960.htm.

7 Shepherd Zhou, "Venerable Canton Gauze Goes Glamorous," *China Pictorial*, May 2007, http://www.rmhb.com.cn/chpic/htdocs/english/200705/200709-200702.htm.

8 "Mudsilk Fabric: 100% Natural Dyeing Fabric Mud Silk," Unknown Blogger, Blogspot, http://mudsilkfabric.blogspot.ca/2009/01/100-natural-dyeing-fabric-mud-silk.html. (accessed 25th June, 2012)

9 Zhou, http://www.rmhb.com.cn/chpic/htdocs/english/200705/200709-200702.htm.

10 Shu Hwa Lin and Kelly Mammel, "Dye for Two Tones: The Story of Sustainable Mud-Coated Silk," *Fashion Practice* 4, no. 1 (2012), p100.

11 Unknown Blogger, http://mudsilkfabric.blogspot.ca/2009/01/100-natural-dyeing-fabric-mud-silk.html.

Mud-silk has several names, including Canton or Guangdong silk, gambiered silk, gambiered Canton gauze, lacquered silk, Tang silk, tea silk, gummed silk (referring to the finish, not raw silk filaments) and scopolamine voile.[14,15] Mud-silk is water-resistant, and reputedly cool and comfortable to wear in warm weather; this, in addition to its cultural significance, made and still makes mud-silk an extremely desirable fabric to own and wear.[16,17]

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12 Valery M. Garrett, *Traditional Chinese Clothing in Hong Kong and South China, 1840 - 1980* (New York, 1987), pp72-73.

13 "香雲紗 / La Soie Gommee / Mud Silk," Bonnie Tchien Hy, Facebook, https://www.facebook.com/media/set/?set=a.135161656655722.1073741832.135129689992252&type=1. (accessed 19 February, 2013)

14 Zhou, http://www.rmhb.com.cn/chpic/htdocs/english/200705/200709-200702.htm.

15 Abby Lillethun, "Black Silk, Brown Silk: China and Beyond - Traditional Practice Meets Fashion," *The Textile Society of America 11th Biennial Symposium 2008 Conference Proceedings*, (Lincoln: University of Nebraska, 2008).p1

16 Margaret T. Ordoñez, "Black Silk, Brown Silk: China and Beyond - Fabric Analysis," *The Textile Society of America 11th Biennial Symposium 2008 Conference Proceedings*, (Lincoln: University of Nebraska, 2008)., p2

17 Lin, Lillethun, and Ordoñez, p103.

1.3 Significance of mud-silk

Although mud-silk is not widely known of, a review of the literature has shown that it has high cultural significance for a number of reasons.

Firstly, the production of a fabric with a finish derived from mud appears to be unique. Other cultures use iron-rich mud and tannin-rich dyes to produce black coloured silk and cellulosic textiles; however none of these textiles are similar to mud-silk.[18,19,20] In the Japanese dyeing process of *Dorozome*, silk dyed by using wood from the *sharinbai* tree is massaged with a slurry of iron-rich mud from rice fields. [21] The production of *Bogolafini* or Bogolan mud cloth in Mali, West Africa employs tannin-rich dyes and iron-rich mud to apply patterns to cotton fabric.[22,23] In Europe, dyeing wool and other fibres black with tannic acid from various plant materials and iron dissolved in

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[18] John Marshall, "Dorozome: Japanese Mud Dyeing," *Turkey Red Journal* 17, no. 1 (2011), http://www.turkeyredjournal.com/archives/V17_I11/Marshall.html.

[19] M. Marquet and P. C. M. Jansen, "Combretum Glutinosum," In *PROTA 3: Dyes and tannins/Colorants et tanins*, ed P. C. M. Jansen and D. Cardon. (Wageningen, Netherlands: PROTA, 2005), http://database/prota.org/PROTAhtml/Combretum%20glutinosum_En.htm.

[20] Patricia Te Arapo Wallace, "*Ko Te Pūtaiao, Te Ao O Ngā Tūpana*/Ancestral Māori Scientific Practice," in *Whatu Kākahu/Māori Cloaks*, ed. A. Tamarapa (Wellington, New Zealand: Te Papa Press, 2011), p51.

[21] Marshall, http://www.turkeyredjournal.com/archives/V17_I11/Marshall.html.

[22] Marquet and Jansen., http://database/prota.org/PROTAhtml/Combretum%20glutinosum_En.htm

[23] National Museum of Natural History, "Discovering Mudcloth: An *African Voices* Exhibition," (Smithsonium Institution, 2002), http://www.mnh.si.edu/africanvoices/mudcloth/html/index.html?showhtml.

vinegar was popularised in the 15th Century.[24] While the European dyeing process does not use mud as the source of iron, the principal for achieving a dark colour is the same as for mud-dyeing processes. Of all the known examples of colouring textiles black using the iron-tannin method, mud-silk is the only one where the black colour is only applied to one side of the textile, leaving the other side orange-brown. This shows that mud-silk is an important product of a unique production technique and skills that find their origins in China.[25]

As well as being unique, the production of mud-silk is also extremely labour-intensive and inherently limited, making the textile expensive. The production process follows traditional methods that workers require extensive training to master.[26,27,28] Production is also limited to specific months during the year, dependent on the number of sunlight hours per day, temperature range and a low relative humidity.[29,30,31] For these reasons only a

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[24] Robin L. Berry, "Dyeing with Tannic Acid and Iron: Walnut Husks,"(2005), http://www.bayrose.org/Poppy_Run/dyeing2_web.pdf.

[25] Han, http://paper.sznews.com/szdaily/20070517/ca22665960.htm.

[26] ———, http://paper.sznews.com/szdaily/20070517/ca22665960.htm.

[27] Zhou, http://www.rmhb.com.cn/chpic/htdocs/english/200705/200709-200702.htm.

[28] Lin, Lillethun, and Ordoñez, p108.

[29] Lin and Mammel, p100.

[30] Han, http://paper.sznews.com/szdaily/20070517/ca22665960.htm.

[31] Zhou, 12http://www.rmhb.com.cn/chpic/htdocs/english/200705/200709-200702.htm.

limited supply of mud-silk is produced a year; this combined with the high production cost gives the end product a high market value.[32,33]

Some varieties of mud-silk are valuable regardless of them having undergone the unique finishing process. A kind of mud-silk known as *xiang-yun-shā* has designs woven into it by dislocating warp threads to create spaces in the weave structure (known as 'leno weave').[34,35,36] The spaces are strategically placed to create patterns depicting traditional Chinese symbols, each with a different meaning.[37] Lin hypothesises that these patterns were inserted for symbolic cultural reasons as well as aesthetic ones, giving the fabric a high cultural significance.[38] The weaving of these patterns into fabrics was also presumably time-consuming and required a high degree of skill. These two factors gave *xiang-yun-shā* high cultural and intrinsic value even before the dye and mud finish were applied.[39]

In addition to being the embodiment of a significant manufacturing practice, and a culturally and intrinsically valuable textile in its own right, mud-silk

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32 Shu Hwa Lin, "Analysis of Two Chinese Canton Silks: Jiāo-Chou and Xiang-Yun-Shā," *The Textile Society of America 11th Biennial Symposium 2008 Conference Proceedings*, (Lincoln: University of Nebraska, 2008).

33 Han, http://paper.sznews.com/szdaily/20070517/ca22665960.htm.

34 Lin, p2

35 Lin, Lillethun, and Ordoñez, p108.

36 Marjorie A. Taylor, *Technology of Textile Properties* (Odiham, Hampshire, UK, 1990), p86.

37 Lin, p3

38 ———, p5

39 ———, p5

can also provide a window into the trade and social history of Southeast Asia and China. Traditionally produced in the Pearl River Delta area in Guangdong, China, it is suggested that mud-silk was made and worn as early as the 5th Century and exported from Guangdong as early as the 15th Century.[40,41] According to Garrett, mud-silk was especially favoured by the Tanka people (a sea-dwelling cultural minority from the coast of the Fujian and Guangdong provinces[42]), because it is water resistant and does not cling to the body when wet.[43,44,45] Lillethun suggests that even though mud-silk was a high-cost material, it was highly sought-after by non-elites because of its practicality.[46] Strongly associated with the Han cultural subgroup rather than the elite Imperial class, there is speculation that mud-silk became a symbol of Han non-imperial identities during the Chinese rebellion and revolution in 1912.[47,48] It is clear that mud-silk is entwined in Chinese social history, making it a significant textile to study, as historically interest in the everyday clothes of working people and cultural minorities in China paled in comparison to interest in brightly coloured, elaborately embellished Imperial dress.[49]

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[40] Lin and Mammel, p97.

[41] Valery M. Garrett, *Chinese Clothing: An Illustrated Guide* (New York, 1994), p196.

[42] Mary Chan Ma Lai, "Egg Woman's Daughter," *Manoa* 10, no. 1 (1998), p81.

[43] Ordoñez, p4

[44] Lillethun, p3-4

[45] Garrett, *Chinese Clothing: An Illustrated Guide*, p196.

[46] Lillethun, p3

[47] Lin, Lillethun, and Ordoñez, p103-105.

[48] Lillethun, p7

[49] Antonia Finnane, *Changing Clothes in China: Fashion, Modernity, Nation* (New York, 2008), p3.

Supposedly because of its cultural significance and intrinsic value, people took mud-silk with them when they emigrated from Southeast China in the late 19th and early to mid-20th centuries.[50,51,52] This explains its presence in areas in North America that had an influx of Chinese immigrants at the turn of the 20th Century, such as Hawai'i (U.S.A.) and Victoria (British Columbia, Canada).[53]

Still produced today, mud-silk fills a high-end luxury niche in the fashion industry, also trickling down to retailers in Southeast China.[54,55] Southeast Asian designers and designers with Southeast Asian heritage also create and market their mud-silk garments around the world, focusing on their return to cultural roots.[56,57] Some designers appeal to the 'eco-friendly' market by placing emphasis on mud-silk's natural origins and advertising their connection with nature.[58,59]

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50 Lillethun, p3

51 Lin, Lillethun, and Ordoñez, p103.

52 Lin and Mammel, p97.

53 Lillethun, p3

54 Lin and Mammel, p106.

55 "Discover China's Top 10 Local Luxury Brands," Luxury Must Hospitality, http://luxurymust-hospitality.com/discover-chinas-top-10-local-luxury-brands/. (accessed 19th February, 2013)

56 Lin and Mammel, pp104-105.

57 Tchien Hy, https://www.facebook.com/media/set/?set=a.135161656655722.1073741832.135129689992252&type=1.

58 Lin and Mammel, pp104-105.

59 "Silk Story," EarthenSilk™, http://www.earthensilk.com/silk.php. (accessed 29th July, 2013)

1.4 Conservation issues for mud-silk

Given that mud-silk is a significant textile for the reasons outlined above, it is important to ensure the preservation of historical mud-silk examples. This will allow the development of the craft through to the present day to be studied, and the social and trade history associated with mud-silk to be communicated.

To understand how mud-silk can best be preserved, we must first understand the issues surrounding its degradation. Little published work is available documenting the condition and conservation of mud-silk, therefore a limited view on its conservation issues can be presented. When examining a mud-silk jacket, Lin et al. noted several conditions common in historical textiles, including wrinkling and creasing from folding and compression in storage, overall surface soiling, white tide lines typical of perspiration stains, white food-like deposits and abrasion from wear.[60] From the author's personal experience with mud-silk garments donated to the RBCM, mud-silk is also susceptible to insect damage, mould growth and flaking of the surface finish, as outlined in the Introduction. These conditions can cause weakness and damage to fibres through both mechanical and chemical methods, and conservation aims to both strengthen areas at risk of being lost and prevent further damage from occurring. Treatments also sometimes aim to improve

[60] Lin, Lillethun, and Ordoñez, pp112-113.

the visual appearance of a textile, to allow it to be better viewed as a whole or to preserve its artistic integrity.[61]

While black iron-tannin dyes have long been known to cause degradation in textiles and paper,[62] no fibre degradation or weakness was observed by the author while examining the RBCM's mud-silk collection, or by Lin et al. This could be for a number of reasons. Firstly, the chemical degradation may not be advanced enough to noticeably affect fibre strength. Secondly, this kind of black dye does not always result in degradation; some mud-dyed plant leaf objects in New Zealand are very fragile and degraded, while others of a similar age are in good condition.[63] Thirdly, there may be some aspect of mud-silk's production process that creates a barrier between the iron-tannin complexes on the textile's face and the fibres in the textile structure, thus reducing the ability of the dye to catalyse fibre degradation.

It appears that mud-silk has mostly been treated in the manner of other textiles, as exhibited by Lin et al.'s wet cleaning treatment of a mud-silk jacket.[64] That mud-silk has been wet-cleaned is not necessarily an indication

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[61] Rachel Langley and Philippa Sanders, "The Visual Reintegration of Missing Areas in Tapestries," in *Tapestry Conservation: Principles and Practice*, ed. F. Lennard and M. Hayward (Oxford: Butterworth-Heinemann, 2006), pp131-132.

[62]Patsy Orlofsky et al., "Recording Change: 1978-2008: The Cleaning of a Needlework Sampler," in *Textile Conservation: Advances in Practice*, ed. F. Lennard and P. Ewer (Oxford: Butterworth-Heinemann, 2010), p168.

[63] Wallace, p53.

[64] Lin, Lillethun, and Ordoñez, p113.

that it should be; more research is required into this and other areas of mud-silk conservation, however this is not the focus of the current investigation. Anecdotally, stitching through mud-silk is difficult and likely to pierce small holes through the surface finish.[65] Textile conservators are accustomed to finding creative solutions when typical stitching treatments are not possible; therefore neither is research in this field the most pressing concern. The flaking condition noted in the RBCM jacket, however, is a condition textile conservators are less likely to be able to address based on a lack of prior experience and limited time available for research, hence the focus of this investigation.

1.5 Mud-silk surface flaking

Information regarding the production of objects can aid in knowing why and how they degrade and what treatments will be best to use. Further discussion of the nature of the surface finish on mud-silk is therefore merited, as it can aid in the conservation decision-making process and give direction to research efforts.

The presence of iron has been confirmed on the surface of mud-silk using Electron Dispersive Spectroscopy.[66] While no proof of an iron-tannin complex has been found in mud-silk, research carried out on Bogilan mud

[65] Kjerstin Mackie, Conversation with author, 2012.

[66] Ordoñez, p2

cloth from Mali has shown that there is a correlation between the chemical structures of iron-gall ink (known to contain iron-tannin complexes) and the African mud-dye.[67] It follows that mud-silk probably contains the same chemical complex, making the mud-treated surface appear black. Given the propensity for iron gall ink and mud-dye to severely degrade paper and textile fibres, an initial hypothesis was that the flaking condition in the RBCM jacket could have been due to detaching fragments of black-dyed silk fibres from the textile surface.[68]

Microscopic examination of mud-silk by the author revealed that the black surface colour does not appear to penetrate the silk fibres, as is normal in dyed fabrics, but is part of a thin, resin-like film on the surface of the textile. This film can be mechanically removed, revealing the orange-brown-dyed fibres underneath. This leads to the suggestion that spreading the mud on the dyed silk surface during production results in the formation of iron-tannin complexes with excess dye on the surface of the textile. No sources are able to explain exactly how the black colour is prevented from penetrating the textile structure and fibres, however it is possible that starch or some other component in the dye extract acts as a physical barrier.[69]

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[67] Mutka V. Limaye et al., "On the Role of Tannins and Iron in the Bogolan or Mud Cloth Dyeing Process," *Textile Research Journal* (2012).

[68] Orlofsky et al., p168.

[69] Lin, Lillethun, and Ordoñez, p108.

Due to the generally robust condition of silk fibres in the RBCM jacket and the ability to mechanically remove the black surface film from mud-silk, it is most probable that the flakes observed were flakes of surface film rather than black-dyed fibre fragments. It follows that treatment of the condition should not be approached in the manner of consolidating brittle textiles, but instead using techniques targeted for the consolidation of a surface film (i.e., a paint or other finish) on a flexible textile. This leads to the investigation of painted textile consolidation.

CHAPTER 2 CONSOLIDATION OF PAINT ON FLEXIBLE SURFACES: A LITERATURE REVIEW

2.1 Introduction

As discussed in section 1.5, the surface finish on mud-silk is a film that can crack and flake, similar to painted textiles, thus a review of the consolidation of painted textiles is pertinent. The principles behind painted textile consolidation are discussed, as understanding of them allows informed decisions to be made regarding treatment parameters, which impact the result of any consolidation treatment. This chapter also reviews consolidants commonly used by paintings and textile conservators, providing a rationale for their testing in the investigation.

2.2 Underlying principles of painted textile consolidation

Most published literature on the consolidation of painted textiles is fairly recent, and usually in the context of painted flags, banners and hangings, with authors drawing on the more established work of canvas paintings conservators.[70,71,72,73,74,75] Reported consolidation treatments of three-dimensional textiles are less prevalent; examples include three Ballets Russes costumes at the National Gallery of Australia (NGA), a painted Egyptian shroud at the Textile Conservation Centre, and a group of painted Mummy cloths at the British Museum.[76,77,78,79]

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[70] Nicholas Eastaugh, Linda Eaton, and Sally Legg, "Painted Textiles," *ICOM-CC 7th Triennial Meeting 1984 Conference Proceedings*, D. d. Froment, 84.89.15-16 (Paris: International Council of Museums, 1984).

[71] Nanette T. Muir and Nicola S. Yates, "Conservation of Painted Flags Using Beva 371," *Conservation News* 26(1985).

[72] ———, "The Treatment of Painted Flags and Banners at the National Maritime Museum, Greenwich," *ICOM committee for conservation: 8th triennial meeting 1987 Preprints*, K. Grimstad, 397-400 (United States Getty Conservation Institute 1987).

[73] Frances Lennard and Vivian Lochhead, "United We Stand! The Conservation of Trade Union Banners," *Tales in the Textile: The Conservation of Flags and Other Symbolic Textiles, NATCC 2003 Preprints*, J. Vuori, (New York: New York State Museum, 2003).

[74] Nancy R. Pollak, "Moving Pictures: Adapting Painting Conservation Techniques to the Treatment of Painted Textiles," *Tales in the textile: The conservation of flags and other symbolic textiles, NATCC 2003 Preprints*, J. Vuori, 127-134 (New York: New York State Museum, 2003).

[75] Miriam McLeod, "Powdery Paint: The Use of Funori with an Indian Jain Painting," *Taking the Rough witht the Smooth: Issues and Solutions for Decorated Surfaces. Forum of the ICON Textile Group 2012 Postprints*, A. Fairhurst, 17-22: The Institue of Conservation, 2012).

[76] Hannah Barrett, "Evaluating Painted Surface Treatments of the National Gallery of Australia's Bellets Russes Costume Collection," *Taking the Rough with the Smooth: Issues and Solutions for Decorated Surfaces. Forum of the ICON Textile Group 2012 Poster*, A. Fairhurst, 70: The Institute of Conservation, 2012).

[77] Tom Bilson, "The Conservation of a Roman Egyptian Painted Shroud Fragment," *The Conservator* 16, no. 1 (1992).

2.2.1 From paintings to painted textiles

Paintings on canvas and painted textiles both have a paint film applied to the textile surface; however, this is where the similarities end. Canvas paintings are usually designed to be immobile, while painted textiles are designed to be mobile, with mobility playing a key role in the function and aesthetics of the textile.[80] This means that rather than being fixed, the direction and intensity of tensions the textile is subject to are dynamic, affecting the stability of the paint film. Damage to the paint film therefore tends to occur most often from fabric flexing and movement over time; brittle paint cracks along the weave structure, resulting in tiny flakes that can easily detach.[81] As in canvas paintings, paint films on mobile textiles can also crack because of differential swelling of fibres and paint films in high moisture environments, a characteristic that is most often cited when wet cleaning is being considered.[82,83] Pollak suggests that painted textiles should be treated in the manner of crumbling, under-bound paint using matte paint consolidation

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[78] Jane Wild, "Isinglass: Consolidating Powdering Pigment on a Painted Linen Border at Normansfield Theatre," *AICCM Textile Symposium 2004 Preprints*, 2004).

[79] Hillyer, "The Conservation of a Group of Painted Mummy Cloths from Roman Egypt," *Studies in Conservation* 29, no. 1 (1984).

[80] Pollak, p128

[81] ———, p131

[82] ———, p131

[83] Eastaugh, Eaton, and Legg, p84.9.15

techniques, as matte paints similarly are not especially stable against mechanical stress.[84]

2.2.2 Matte paint consolidation and painted textiles

Matte paint films tend to have little or no binder, meaning they have poor adhesion and cohesion and easily become flaky or powdery.[85,86] Consolidation of matte paint usually employs water-based consolidants, such as cellulose ethers and gelatine, and sometimes multiple applications of a dilute solution to avoid changes in appearance such as darkening, tide lines and gloss.[87] Over-application of a consolidant is the main cause of darkening and gloss; complete filling of the voids in the paint structure increases the colour saturation, and excess consolidant on the surface of the paint reflects more light.[88,89] Dilute solutions allow for more control of the amount of consolidant applied, thus over-application and its associated effects can be avoided.[90] Tide-lines are usually the result of uneven application, which is also less likely to occur with dilute, less viscous solutions.[91,92] The

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84 Pollak, p131

85 Thomas Geiger and Françoise Michel, "Studies on the Polysaccharide Junfunori Used to Consolidate Matt Paint," *Studies in Conservation* 50(2005), p193.

86 Eric F. Hansen and Rosa Lowinger, "Investigations into Techniques for the Consolidation of High Pigment Volume Concentration Paint at the Getty Conservation Institute," *WAAC Newsletter* 12, no. 3 (1990), http://cool.conservation-us.org/waac/wn/wn12/wn12-13/wn12-307.html.

87 Hansen and Lowinger, http://cool.conservation-us.org/waac/wn/wn12/wn12-13/wn12-307.html.

88 McLeod, p20

89 Hansen and Lowinger, http://cool.conservation-us.org/waac/wn/wn12/wn12-13/wn12-307.html.

90 McLeod, p20

91 McLeod, p20

penetration of the consolidant into the paint film is therefore a key variable in the success of the treatment and its visual effect, alongside the amount of consolidant being carried into the film with each application and the number of applications carried out.

Controlling penetration is also important when consolidating painted textiles, in order to control both the effect on fabric flexibility and the paint appearance. This is because when a consolidant deeply penetrates a textile it fills air spaces between fibres and adheres them together, limiting movement between yarns and fibres, thus decreasing the fabric's ability to bend.[93] While paint films on painted textiles may very well be matte, even non-matte paint on textiles can behave and degrade in the same way as matte, under-bound paint due to cracking along weave interstices. Unlike static canvas paintings, a key criterion for a painted textile consolidation treatment is the ability to stabilise the flaking paint film without impregnating the textile or greatly affecting its flexibility.[94,95] This is because noticeable change in the flexibility and drape of a garment after consolidation would affect its shape and nature, altering historical interpretation.[96] It is therefore desirable to achieve a consolidation treatment with no noticeable change in these properties.

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92 Hansen and Lowinger, http://cool.conservation-us.org/waac/wn/wn12/wn12-13/wn12-307.html.

93 Gustav A. Berger and Harold I. Zeliger, "Effects of Consolidation Measures on Fibrous Materials," *Bulletin of the American Institute for Conservation of Historic and Artistic Works* 14, no. 1 (1973), p47.

94 Eastaugh, Eaton, and Legg, p84.9.15

95 Bilson, p5.

96 Barrett, p70

2.2.3 Three-dimensional painted textiles

While theory and practice developed for the consolidation of canvas paintings has successfully been applied to and adapted for painted flags, banners and hangings, little has been published on applications to textiles used in garment construction with a paint film or surface finish. The consolidation of the Ballets Russes costumes at the NGA is one of few published accounts of the treatment of painted costume, evaluating Mowilith DM4 (production now discontinued), gelatine and isinglass consolidation treatments.[97] Accounts discussing the consolidation of painted Egyptian burial textiles highlighted the importance of maintaining textile flexibility, finding that low concentrations of Paraloid-B72 in xylene were effective at consolidating paint and maintaining flexibility.[98,99] Haldane describes the conservation of a Chinese painted silk dress, however the paint was not unstable enough to warrant consolidation, with only support of the split silk being carried out.[100] While flags, banners and hangings are flexible and mobile, they are large, two-dimensional and often heavy; garments require textiles to be eased and manipulated into a three-dimensional configuration and are typically more lightweight and flexible. It follows that the requirement for treatments minimally affecting textile flexibility is even more

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[97] Barrett, p70

[98] Hillyer, p5.

[99] Bilson, p6.

[100] Haldane, http://www.vam.ac.uk/content/journals/conservation-journal/issue-49/encounters-with-paper-conservation-the-treatment-of-a-chinese-painted-silk-dress/.

important when treating costume objects made of painted or finished textiles.

2.2.4 Factors affecting consolidant penetration

While the properties of a resin or polymer affect adhesive bond strength and film flexibility, penetration of the consolidant into the paint and textile is often more dependent on the solution properties and application method. Discussions by Ebert et al. and Hansen and Lowinger are reviewed below.[101,102]

Low-viscosity and high-wetting properties allow greater penetration, providing good cohesion within the paint film and adhesion between the paint and textile, but potentially impregnating the textile with consolidant, affecting flexibility. Consolidants with high viscosity and low-wetting (i.e., high surface tension) have decreased penetration, however new flakes can be dislodged, as the bonding between solvent and paint can be stronger than cohesive forces within the paint. For this reason surfactants are sometimes added to consolidant solutions to reduce surface tension and prevent paint disruption, while maintaining high viscosity to limit penetration. Incorporating volatile solvents into the solution can also help control penetration; as the solvent evaporates the solution viscosity increases,

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[101] Bettina Ebert, Brian Singer, and Nicky Grinmaldi, "Aquazol as a Consolidant for Matte Paint on Vietnamese Paintings," *Journal of the Institute of Conservation* 35, no. 1 (2012), p66-67.

[102] Hansen and Lowinger, http://cool.conservation-us.org/waac/wn/wn12/wn12-13/wn12-307.html.

allowing fast initial penetration into the paint film and slower subsequent lateral spreading through the textile.[103] Application using a medical nebuliser or ultrasonic mister also regulates penetration through the controlled application of small droplets of consolidant.[104]

2.3 Common consolidants

Literature on consolidants commonly used in paintings and textile conservation informed the consolidant choices and preparation methods used in this investigation. Consolidants most often used in textile conservation are isinglass and Beva® 371.[105,106,107] Other consolidants commonly used for matte paint, and less commonly for painted textiles, include funori, Aquazol®, Paraloid B-72, gelatine, methylcellulose, hydroxypropyl cellulose and Lascaux 4176 (acrylic resin).[108,109,110,111,112,113]

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103 Pollak, p131

104 McLeod

105 Sarah Foskett, "An Investigation into the Properties of Isinglass," *SSCR Journal* 5, no. 4 (1994), p11.

106 Lennard and Lochhead, p115

107 Muir and Yates, "Conservation of Painted Flags Using Beva 371," p24.

108 McLeod, p19

109 Julie Arslanoglu, "Aquazol as Used in Conservation Practice," *WAAC Newsletter* 26, no. 1 (2004), p10.

110 Lisa Cumming and Jane Colbourne, "The Conservation of Mrs. Marton, an Eighteenth-Century Pastel and Gouache Portrait by Daniel Gardner," *The Paper Conservator* 22, no. 1 (1988), p41.

111 Gillian M Lewis, Nanette T. Muir, and Nicola S. Yates, "The Link between the Treatments for Paintings and the Treatments for Painted Textiles," *Fourth International Restorer Seminar 1984 Conference Proceedings*, Á. Tímár-Balázsy, 169-182 (Budapest: National centre of museums, 1984).p178

112 Frances Lennard, "The Conservation of the United Tin Plate Workers' Society Banner of 1821," *The Conservator* 13, no. 1 (1989), p5.

113 Ursula Haller, Stephanie Hilden, and Karin Krüger, "The Ermlitz Project: Conservation and Mounting of 310 Square Metres of Painted Wall Hangings," *Studies in Conservation* 57(2012), p142.

Because it was not possible to test all consolidants, the choice was narrowed to three. Isinglass was chosen as it is the most-used consolidant in textile conservation, and it was decided that the two other consolidants should be comparable in terms of solubility. For this reason funori and Aquazol® were chosen, as they are soluble in water (while others such as Beva® 371 and Paraloid B-72 are not), and had performed well for the consolidation of matte paint.[114,115] A more extensive review of the literature was undertaken for the three chosen consolidants.

2.3.1 Isinglass

Information regarding the properties of and common techniques used with isinglass was found from Wild, Foskett, Barrett, Lennard, and Geiger and Michel.[116,117,118,119,120]

Isinglass is a gelatine product derived from fish swim bladders, historically those of sturgeon. It is water-soluble, non-toxic, pH neutral, high wetting, stable to light and thermal ageing, and has good flexibility and excellent

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114 McLeod, p21

115 Ebert, Singer, and Grinmaldi, pp70-71.

116 Wild, p51

117 Foskett, pp11-12.

118 Barrett, p70

119 Lennard, p5.

120 Geiger and Michel, p196.

adhesive properties.[121] While Lennard found that the viscosity of isinglass aided in limiting penetration into textiles, causing little discolouration and stiffening, Foskett observed that viscosity varies according to the temperature at which it is used and the source of the product.[122,123] There is some indication that isinglass may be susceptible to microbiological attack, although this has not been extensively investigated.[124] Isinglass is usually applied warm (between 40 and 60ºC) at concentrations ranging from 1 to 3%. Heat and pressure is often applied to painted surfaces after consolidation with isinglass in order to improve contact between paint, consolidant and substrate, and to relax and plasticise the paint. While isinglass has a long history of use in conservation, and is widely regarded as a superior consolidant, there has recently been some discussion of the environmental and ethical implications of its continued use, with 23 of the 27 known sturgeon species being classified as 'threatened'.[125]

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121 Oliver Masson and Michaela Ritter, "'Fräulein Huth' and the Red Seaweed: Consolidation of a Collage by Kurt Schwitters with Junfunori®," *The Paper Conservator* 28, no. 1 (2004), p95.

122 Lennard, "The Conservation of the United Tin Plate Workers' Society Banner of 1821," p5.

123 Foskett, p12.

124 ———, p12.

125 Barrett, p70

2.3.2 Funori

The general properties and uses of funori are described by Swider and Smith, Masson and Ritter, and McLeod, which are the sources contributing to the below review.[126,127,128]

Funori is a polysaccharide polymer obtained from red seaweed cultivated off the coast of Japan, sometimes used in a purified powder form known as JunFunori®. JunFunori®, produced by Lascaux, is claimed to have greater adhesive strength and fewer impurities than regular funori, and is accordingly more expensive. In this section, 'funori' is used to refer to the consolidant solution made from either raw or purified sources. Funori is water-soluble, non-toxic, high wetting with good penetration, dries matte and is fairly stable in artificial ageing tests. While funori can become bleached with exposure to extreme lighting conditions, it retains its flexibility and does not yellow. Swider and Smith found that painted objects and a painted textile consolidated with funori did not appear to have any problems when examined 25 years after treatment.[129] McLeod reports that funori was successfully used to consolidate powdery, matte paint on a painted textile hanging without any visual changes, however no comment is made on the effects on the flexibility of the textile.[130] There is speculation that funori is

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[126] Joseph R. Swider and Martha Smith, "Funori: Overview of a 300-Year-Old Consolidant," *Journal of the American Institute for Conservation* 44, no. 2 (2005).

[127] Masson and Ritter, pp94-95.

[128] McLeod,

[129] Swider and Smith, p123.

[130] McLeod, p21

resistant to microbiological attack, however this mainly arises from the fact that no evidence of microbiological activity has ever been observed on funori-treated objects, and more research is required to confirm this property. While used commonly for consolidating paint on paper, paintings and wood, funori is less routinely used for the treatment of painted textiles. Highly viscous at concentrations as low as 1%, funori is normally used at concentrations between 0.2 and 0.3%, sometimes with numerous applications to achieve the desired adhesive strength. Funori is sometimes mixed with isinglass to achieve a lower viscosity and increase its adhesive strength, while maintaining a matte finish.[131]

2.3.3 Aquazol®

The sources consulted for the following section on Aquazol® were Bossetti, Ebert et al., Arslanoglu, and Arslanoglu and Tallent.[132,133,134,135]

Aquazol® is a poly(2-ethyl-2-oxazoline) synthetic polymer that has been used in conservation since the 1990s, and comes as solid crystals that can be dissolved in water or polar solvents. Four different grades are produced, 5,

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131 Masson and Ritter, pp94-95.

132 Elisabetta Bosetti, "A Comparative Study of the Use of Aquazol in Paintings Conservation," *e-conservation magazine* 24(2012), http://www.e-conservationline.com/content/view/1073.

133 Ebert, Singer, and Grinmaldi, pp70-71.

134 Julie Arslanoglu and Carolyn Tallent, "Evaluation of the Use of Aquazol as an Adhesive in Paintings Conservation," *WAAC Newsletter* 25, no. 2 (2003).

135 Arslanoglu and Tallent, p12.

50, 200 and 500 (corresponding to the molecular weight), the higher three of which are available to conservators. Aquazol® is pH neutral, non-toxic, has good thermal and photochemical stability, and has a low viscosity for its molecular weight, meaning that higher concentrated solutions still have good flow properties. A disadvantage of Aquazol® is its tendency for higher moisture uptake than isinglass and gelatine at high relative humidity (RH) levels over 75%, resulting in creep and loss of adhesion, although it retains good flexibility at low RH. Arslanoglu and Tallent found that Aquazol® prepared in alcohol had less moisture uptake than that prepared in deionised water.[136]

The choice of grade is often dependent on the degree of penetration needed versus the desired bond-strength, as higher molecular weights provide a stronger bond but less penetration of the paint, and vice versa.[137] Often conservators opt for Aquazol® 200 as this provides medium penetration and bond strength, however layering and blending of different grades is sometimes used to utilise their respective properties. According to a survey carried out by Arslanoglu, Aquazol® is most often used at concentrations between 5 and 10%, although Ebert et al. found that a 2.5% solution of Aquazol® 200 in propan-2-ol worked best for matte paint consolidation.[138,139] Bosetti suggests that Aquazol® may present an 'environmentally compatible

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[136] Arslanoglu and Tallent, p14.

[137] Arslanoglu, "Aquazol as Used in Conservation Practice," p10.

[138] Arslanoglu, p10.

[139] Ebert, Singer, and Grinmaldi, p68.

alternative to animal glue', which may be considered by institutions finding isinglass ethically uncomfortable.[140]

[140] Bosetti.p73

CHAPTER 3 THE EVALUATION OF FABRIC FLEXIBILITY

3.1 Introduction

As seen in Chapter 2, a key concern in consolidating a garment made of mud-silk or painted textile is to retain the garment's flexibility and drape to maintain its aesthetic integrity. It is therefore not enough for a consolidation treatment to successfully stabilise a garment's flaky paint film or surface finish; it must also have little or no perceivable effect on the garment's visual properties. In order to assess whether a consolidation treatment does not perceivably change the appearance of mud-silk, some method of treatment evaluation must be employed.

For an interventive treatment, the conservator undertaking the work usually subjectively evaluates the appropriateness of the treatment options through preliminary tests on a similar material, as well as discrete in situ tests. For example, if an adhesive silk crepeline overlay is to be applied to a textile, the conservator would test a range of adhesives, concentrations and application methods and evaluate the appropriateness of each based on attributes such as bond strength, stiffness and surface gloss. Test parameters can often be narrowed by the requirement of certain properties, for example surface tack, but some degree of testing is normally necessary as each object is different and has specific treatment requirements. Sometimes subjective evaluations are supported by assessments made by a handful of colleagues, and rating systems can be employed to allow better interpretation of results.[141] Individual subjective evaluation is extremely important in treatment development, as it allows the conservator to justify their decisions and make informed choices within the time available for treatment.[142] However, this method of evaluation is not the most powerful or robust way of evaluating the attributes of a material or treatment. This investigation sought to provide results that were as reliable and objective as possible, thus a more thorough method of treatment evaluation was sought.

Two well-established and commonly employed methods in the evaluation of textile properties are instrumental evaluation and sensory evaluation. These two methods have different strengths; the former is able to provide sensitive, objective measurements on specific physical properties, while the latter gives an indication of human perception.[143] In order to narrow the research parameters and make best use of the time available for the investigation, research focussed on testing the flexibility of fabric rather than other treatment attributes.

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[141] Wild, p52

[142] Kate Gill and Foekje Boersma, "Solvent Reactivation of Hydroxypropyl Cellulose (Klucel G®) in Textile Conservation: Recent Developments," *The Conservator* 21(1997), p16.

[143] Izabela Luiza Ciesielska-Wróbel and Lieva Van Langenhove, "The Hand of Textiles - Definitions, Achievements, Perspectives - a Review," *Textile Research Journal* 82, no. 14 (2012), pp1458 & 1463.

3.2 Fabric flexibility as a visual attribute

The tactile component of textiles in garments is inherent, and it is clearly an important factor influencing their production, purchase and use.[144] Since textiles were first created, their quality has been assessed through physical manipulation with the hands, described as 'hand'.[145] The hand of a fabric is contributed to by physical properties such as flexibility, drape, thickness, softness and smoothness.[146,147] While fabric hand is important in garments that are worn and touched, it would at first appear less significant for garments in an historical collection, whose purpose is for research and display. Most people who see them do not touch such historical garments in order to ensure their physical preservation; movement can cause physical damage, and oils, dirt and sweat from the hands can cause chemical damage.[148] While historical garments are not often touched, if they are part of a display they are usually mounted on mannequins to provide context and an impression of their form when worn.[149] In presenting a garment in this fashion, its form and physical behaviour are displayed; in other words, some of the same physical properties that influence fabric hand affect the visual impression of the garment. For example, a dress constructed of stiff, starched fabric would appear voluminous and hold its own shape, while a

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[144] Ning Pan, "Quantification and Evaluation of Human Tactile Sense Towards Fabrics," *International Journal of Design and Nature* 1, no. 1 (2007), p48.

[145] Laura Bacci et al., "Sensory Evaluation and Instrumental Measurements to Determine Tactile Properties of Wool Fabrics," *Textile Research Journal* 82, no. 14 (2012), p1430.

[146] Pan, p48.

[147] Ciesielska-Wróbel and Van Langenhove, p1458-1459.

[148] The National Trust, *Manual of Housekeeping* (Swindon, Wiltshire, 2011), pp62&76.

[149] Lara Flecker, *A Practical Guide to Costume Mounting* (Oxford, 2007), pxiii.

dress constructed of fabric that is more flexible would appear flowing. A treatment undertaken on a flowing dress that rendered the textile more stiff would change its flexibility and the way that it draped on a mannequin, thus altering the visual interpretation. Fabric hand is therefore an important factor in the historical interpretation of garments, even though most people do not handle these garments. Given that hand is extremely complex and difficult to reliably assess, and the attribute mainly contributing to fabric behaviour in this instance is flexibility, it is convenient to simplify evaluation to focussing on fabric flexibility, a more easily assessed characteristic. In this case, flexibility is therefore used as an indication of the fabric's visual properties, even though it is normally considered a tactile attribute.

3.3 Instrumental evaluation of flexibility

According to Peirce, physical measurements of a material can provide data on which assessments of that material can be based.[150] Measureable mechanical properties are used to explain either the hand of a textile or individual attributes that contribute to the hand, such as flexibility.[151] This strategy of physical testing, also known as instrumental evaluation, can and has been used to assess the physical effect of conservation treatments on a

[150] F. T. Peirce, "The "Handle" Of Cloth as a Measurable Quantity," *Journal of the Textile Institute Transactions* 21, no. 9 (1930), p378.

[151] Bachik Abu Bakar, "Subjective and Objective Evaluation of Fabric Handle Characteristics" (MSc Dissertation, University of Leeds, 2004), p8.

material, allowing judgement of whether a treatment is acceptable for application to an historical object.[152]

Flexure tests have been used in the past to assess the flexural rigidity of painted canvases after treatment with a range of adhesives.[153] These tests however are only appropriate for rigid or semi-rigid materials, and do not translate well into testing the flexibility of non-rigid materials such as textiles used in garments. Tests used in textile science are therefore more appropriate for evaluating the physical effect of consolidants on textiles. Since the 1930s, methods have been devised and refined by textile scientists to objectively measure textile properties such as tensile strength, extensibility, flexibility, compressibility and drape.[154,155] By measuring these properties it is possible to quantify differences between textile structures, finishing techniques, and, by extension, consolidation treatments.

Peirce discusses that the three parameters of bending length, flexural rigidity and bending modulus can be used to describe fabric flexibility.[156] While

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152 Gustav A. Berger, "Some Effects of Impregnating Adhesives on Paint Films," *Bulletin of the American Institute for Conservation of Historic and Artistic Works* 12, no. 2 (1972), p184.

153 Berger, p184.

154 Gülcan Süle, "Investigation of Bending and Drape Properties of Woven Fabrics and the Effects of Fabric Constructional Parameters and Warp Tension on These Properties," *Textile Research Journal* 82, no. 8 (2012), p810.

155 Lelia J. Winn and Edward R. Schwarz, "Technical Evaluation of Textile Finishing Treatments: Flexibility and Drape as Measurable Properties of Fabric," *Textile Research Journal* 10, no. 1 (1939).

156 Peirce, p379&390.

bending length describes a fabric's resistance to bending under its own weight (a contributing factor to drape), flexural rigidity describes the fabric's flexibility when the effect of specimen weight has been eliminated (stiffness 'as appreciated by the fingers'). Similarly, bending modulus eliminates the effects of both specimen weight and thickness (describing 'paperiness' or crispness). It is therefore possible to use these three values to describe the effect of different consolidation treatments on the hand and behaviour of a textile. This can indicate if and how the appearance of the textile when displayed would be significantly altered by a treatment.

Numerous instrumental devices have been developed to objectively measure the flexibility of fabrics, including but not limited to the variable-angle flexometer (also known as the 'cantilever'), the fixed-angle flexometer, the Planoflex, the Gurley stiffness tester and instruments part of the Kawabata System (KES) and Fabric Assurance by Simple Testing (SiroFAST) system[157,158,159,160,161] Peirce also developed the hanging loop tests for fabrics that are extremely limp or have a tendency to curl, as these properties would

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157 Peirce.

158 Edwin C. Dreby, "The Planoflex, a Simple Device for Evaluating the Pliability of Fabrics," *Journal of Research of the National Bureau of Standards* 27(1941).

159 Winn and Schwarz, p5.

160 Belinda T. Orzada, "Effect of Laundering on Fabric Drape, Bending and Shear," *International Journal of Clothing Science and Technology* 21, no. 1 (2009), p3.

161 A. De Boos and David Tester, "Sirofast: Fabric Assurance by Simple Testing - a System for Fabric Objective Measurement and Its Application in Fabric and Garment Manufacture," (The Commonwealth Scientific and Industrial Research Organisation Textile and Fibre Technology division, 1994).

compromise the results of flexometer tests.[162] All these methods measure flexibility through the relationship between the deformation of a sample and the force required to do so; either a known force is applied and the deformation measured, or a known deformation applied and the force required measured.[163] The wide range of options available may seem overwhelming, however in the context of this investigation the options were significantly narrower due to the availability and cost of equipment. As such, two options were considered for the investigation and were subsequently reviewed.

3.3.1 Fixed angle flexometer

The British Standards Institute stipulates a standard method for measuring the bending length and flexural rigidity of textiles using a fixed angle flexometer.[164] Simple and easy to follow, the method also provides detailed descriptions of the flexometer requirements so that one could be constructed. The apparatus consists of a raised horizontal platform, which is intersected at one end by a plane of a known angle (Figure 3.1). A strip of fabric is slid over the edge of the horizontal platform until its end touches the angled plane; at which point the length of overhanging fabric is measured

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[162] Peirce, p396&401.

[163] Winn and Schwarz, pp5-6.

[164] British Standards Institution, "Bs 3356:1990 Method for Determination of Bending Length and Flexural Rigidity of Fabrics," (British Standards Institution, 1990), p1.

(providing the 'bending length'). The method is not appropriate for fabrics that curl or twist when cut into small pieces.[165]

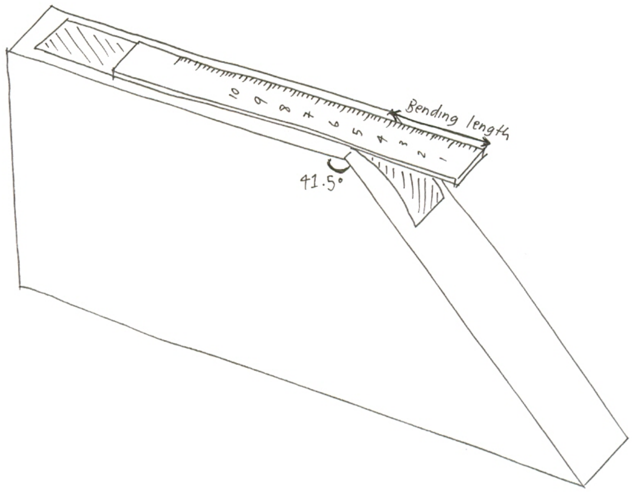

Figure 3.1 – Fixed-angle flexometer

3.3.2 Heart loop method

Of Peirce's loop tests, the heart loop method reportedly achieves the most consistent results for a wide range of fabrics, and has a less complicated mathematic formula for calculating bending length.[166] The heart loop test consists of bending a strip of fabric of a known length into a heart-shaped loop and measuring the distance from the clamped ends to the bottom of the loop (Figure 3.2).[167] This measurement is then used in an equation developed by Peirce to calculate the bending length. While the theory behind the heart

165 British Standards Institution, p1.

166 Winn and Schwarz, p7.

167 Howard L. Price, "Techniques for the Measurement of the Flexural Rigidity of Thin Films and Laminates," (Hampton, Virginia: Langley Research Center, 1966), p4.

loop method is more complicated than that of the fixed-angle flexometer, the method itself is very simple to carry out and does not require any specialised apparatus. It should be noted that specimen length affects results up to a specific length (determined experimentally), after which results are unaffected.[168]

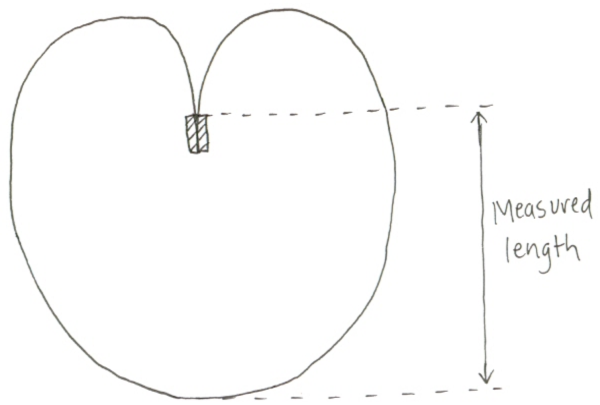

Figure 3.2 – Heart loop test

[168] Winn and Schwarz, p7.

3.4 Sensory evaluation of flexibility

In textile science, sensory evaluation is used to evaluate textile properties as they relate to consumers' perceptions, as it is acknowledged that physical tests do not adequately describe product quality.[169] While sensory evaluation is viewed as being more subjective than instrumental analysis, it is recognised as a valid tool for the evaluation of fabric hand, as it is more applicable to how people perceive textiles.[170] For this reason, sensory evaluation was considered an appropriate method for determining which consolidation treatments perceivably affected the flexibility of mud-silk.

The technique uses the human senses as a measurement tool, and can either produce information about the physical attributes of a product (sensory analysis) or consumers' preferences for product attributes (hedonic analysis).[171] Sensory analysis is undertaken through either discriminative testing, in which the sensory differences between two products are evaluated by non-trained judges, or descriptive analysis, which requires a trained panel to quantify sensory attributes of products in a reliable manner.[172] Descriptive analysis typically takes 20 – 40 hours to train participants, as it relies on all participants concurrently producing and adhering to definitions of the

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[169] Flora Philippe et al., "Tactile Feeling: Sensory Analysis Applied to Textile Goods," *Textile Research Journal* 74, no. 12 (2004), p1066.

[170] Bacci et al., p1431.

[171] Philippe et al., p1067.

[172] ———, p1067.

attributes they are judging.[173] Despite the degree of training required, descriptive analysis is used more often than discriminative analysis as it typically produces more reliable and objective results.[174,175] Discriminative analysis can however be used with a panel of 'experts' (people familiar with handling textiles), as judges will then provide reliable answers without the need for extensive training.[176]

Evaluation of samples can be made using either a sensory evaluation scale, in which each attribute is clearly defined with control fabrics providing scale references, or by paired ranking, where each sample is compared with all others and ranked accordingly.[177,178] The time required for participants to undertake paired comparisons exponentially increases with the number of specimens assessed, meaning that it can be impractical for a large number of textiles.[179] While the scale method provides information that is more detailed, it also has a greater potential for inconsistency among different judges because judges may have a different 'internal scale' to each other. For example, one judge might consider specimens examined to be spaced closely together on the rating scale, while another judge might consider the same specimens to be spaced more widely. This is dependent on each judge's

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173 ———, p1067.

174 ———, p1067.

175 Bacci et al., p1432.

176 Peter Brown, "The Characterization of Bulk," *Textile Research Journal* 39, no. 5 (1969), p403.

177 Vildan Sülar and Ayşe Okur, "Sensory Evaluation Methods for Tactile Properties of Fabrics," *Journal of Sensory Studies* 22(2007), p7.

178 Brown, pp402-403.

179 Sülar and Okur, p7.

sensitivity and personal experience, making it important to provide adequate training to reduce these biases. Conversely, paired ranking only relies on each judge's ability to discern a difference between two specimens, not how different they are. This reduces the potential bias, however also yields less information about the assessed attributes. As there was limited time for this investigation, paired ranking was considered more appropriate because it requires little to no training time, and was therefore researched further.

3.4.1 Paired ranking

General requirements for sensory evaluation tests are that specimens are presented to judges in a random order, testing takes place in a standard controlled environment (65±2% relative humidity and 20±1ºC), and measures are taken to avoid sensory fatigue, such as 15 minute breaks or session times limited to 30 minutes.[180,181] Paired ranking is generally undertaken using Kendall's paired comparison method, where a judge is presented a pair of specimens and asked to record which of the two they consider to rank higher or lower for the attribute assessed.[182,183] This is repeated with all possible paired combinations. Kendall also developed the coefficient of agreement, which allows the agreement among different judges to be calculated and, by

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180 Philippe et al., p1067.

181 Brown, p404.

182 Maurice G. Kendall, *Rank Correlation Methods* (London, 1955), pp144-154.

183 Brown, pp402-403.

extension, the consistency of a single judge across multiple evaluation sessions.[184,185]

While Kendall's method allows more than two specimens to be compared and ranked, it does not adequately allow for a 'no-preference' option for each pair, as the coefficient of agreement essentially assumes that any non-preferential decisions are a result of a judge's inability to be consistent. This may mask the effect of specimen pairs that are so similar they are indistinguishable. If one is interested in only two specimens compared to each other and wants to include a no-preference option, the method developed by Ferris is applicable.[186] Ferris' method also accounts for judges who choose either specimen in the pair in order to 'please the experimenter', thus giving an indication of the proportion of non-discriminating judges who expressed false preferences.[187] To see if either specimen is consistently chosen by judges, a significance test is used; however, this test assumes that the number of participants is >100, preferably >200, therefore Ferris' method is not appropriate for small sample sizes.[188]

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184 ———, p404.

185 Soae L. Paek and M. H. Mohamed, "The Selected Hand Properties of Latex-Bonded Nonwovens," *Textile Research Journal* 48, no. 5 (1978), p283.

186 H. T. Lawless and H. Heymann, "Preference Testing," in *Sensory Evaluation of Food* (London: Springer Science+Business Media, 2010), p313.

187 Lawless and Heymann, pp313-314.

188 ———, p315.

CHAPTER 4 MATERIALS AND METHODS

4.1 Introduction

The method was designed to address the aims outlined in the Introduction. An initial objective was to recreate the flaking condition noted in the RBCM jacket on un-used mud-silk purchased in the 1950s (Aim 1, Objective a). After attempts at this failed, the investigation was separated into two parts. The first part tested a range of consolidants and solution mixtures on new painted silk fabric with similar flaking properties to the RBCM jacket (section 4.3). The second part tested the effect of different successful consolidation treatments on the flexibility of the 1950s mud-silk, to ascertain if different consolidants and treatment methods have a different impact on fabric flexibility (section 4.4).

4.2 Creating flaking samples

4.2.1 Flaking mud-silk

A number of attempts were made to induce the 1950s mud-silk to flake in the same way as the jacket at the RBCM. Small mud-silk samples were subjected to a range of treatments. Methods included flexing, creasing, abrasion, prolonged subjection to high humidity and heat, and subjection to fluctuating humidity over a 12-hour period. A Heraus accelerated ageing oven was used for heat treatments, and an Espec Humidity/Temperature

Chamber (model SH221) for combined heat/humidity treatments and fluctuating humidity treatments. It was not possible to subject samples to more than 12 hours of fluctuating humidity, as the Espec water chamber did not hold enough water to sustain the dry/humid cycle for longer. None of the methods resulted in any form of damage to the mud-silk finish, except wet abrasion, which only resulted in loss of finish rather than flaking. Testing was discontinued due to time constraints.

4.2.2 Painted samples

Rather than replicating the mud-silk flaking condition from the RBCM jacket, a painted textile that could be made to flake in a similar way was created on which to test consolidation treatments. A tempera paint was developed which, when painted onto new silk, could be easily damaged through physical manipulation to create a degree of flaking similar to that seen in the RBCM jacket. Egg yolk mixed with 1% (w/w) deionised water was combined with iron oxide pigment in a ratio of two parts binder to one part pigment. The resulting paint was viscous enough to sit on the surface of the silk, yet fluid enough to achieve a thin coat on the silk that would flake in the desired manner.

Pieces of silk 150mm square were placed on a polythene-covered tabletop, wetted, the grain aligned, and tensioned with masking tape. After drying, the silk was painted with freshly mixed paint and allowed to dry. Each piece was then cut into four sections, each 50mm square. The 50mm squares were caused to flake by bringing the four corners together, crushing and physically manipulating. After opening, each square was tilted to allow excess flakes to fall off and put aside for consolidation (Figure 4.1).

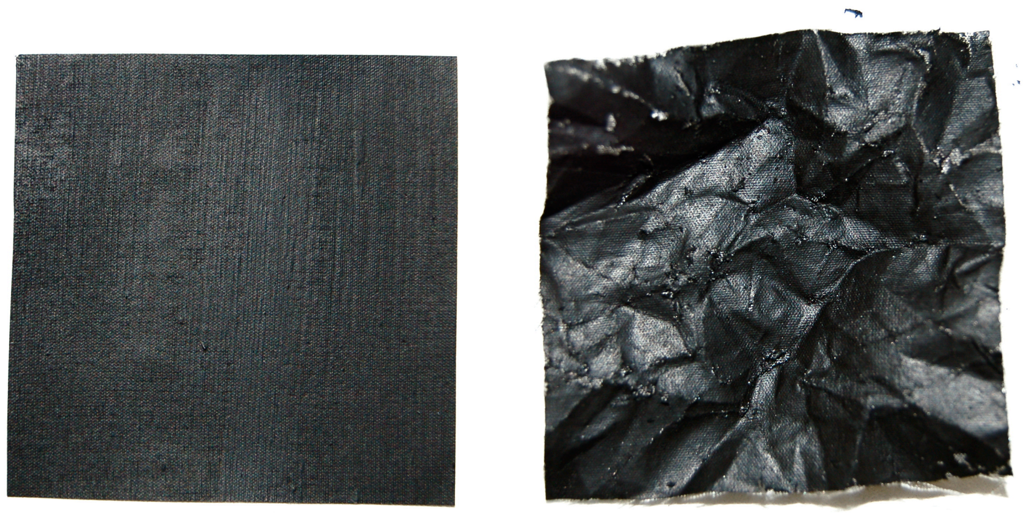

Figure 4.1 – Painted specimen before and after flaking

4.3 Consolidation testing

The purpose of consolidation testing was to find the minimum number of applications required to achieve a successful consolidation treatment on painted samples with a range of consolidants and solvent mixtures.

4.3.1 Preliminary testing

Development of the consolidant application method focused on aerosol application. The options initially considered for testing were brush, aerosol, ultrasonic misting and medical nebuliser systems. Brush application tests revealed that it was very difficult to control the amount of adhesive applied, resulting in a high risk of total fibre saturation that would surely decrease the textile's flexibility, therefore this method was ruled out. Ultrasonic misting was not tested, as the minimum volume required for operation is relatively large due to the size of the liquid reservoir. This was considered too cost-inefficient for consolidating small areas, as the proportion of consolidant required for operation would be more than that required for actual consolidation. Medical nebulisers were also not tested, as they are specialised equipment, making them expensive and uncommon in conservation labs. It was felt that systems tested should be widely accessible to conservators, in both cost and availability.

The aerosol system used was a basic external-mix airbrush ('single action'), meaning that the air and fluid were mixed at the tip of the applicator rather than inside the system. The spray applicator was attached to a compressed air source (airbrush propellant) that was released by depressing a trigger. The fluid reservoir, a small glass bottle containing consolidant, had a thin polyethylene tube connected to a nozzle, through which the consolidant was drawn by air pressure when spraying (Figure 4.2). Depressing the trigger blew air over the nozzle, atomising the liquid at the tip and propelling it in the direction pointed. Raising the nozzle higher into the path of the air stream could increase the volume of liquid dispersed, creating a denser spray.

Figure 4.2 – Airbrush used for consolidant application

A standard technique for holding the airbrush was first developed so that any subsequent tests would not be altered by the angle of spraying. The nozzle was held perpendicular to the treatment surface, meaning that the spray stream approached the surface at an angle of 90°. This technique was chosen with three-dimensional costume in mind; if the costume were on a mannequin, all areas could be treated with minimal handling while holding the airbrush comfortably in the hand with the operator's elbow at their hip. As such, spraying carried out on two-dimensional samples on a table required the operator's elbow to be at the same level as their shoulder (Figure 4.3).

Figure 4.3 – Airbrush technique

Preliminary tests were carried out with the aerosol system using isinglass on painted silk samples to determine the variables influencing application technique and select the most appropriate technique. At the time of testing, isinglass was the only consolidant on hand out of the three that were chosen, thus was used to develop an appropriate method that could be used with all three consolidants. The results of this testing (section 5.1) informed the technique used to apply consolidants in all subsequent tests.

4.3.2 Consolidation of painted samples

As discussed in section 2.3, isinglass, Aquazol® 200 and funori were chosen for their similar solvent compatibilities and precedence in painted textile and matte paint consolidation. Consolidants were applied to painted, flaked specimens using a Beaver® external-mixing airbrush system with the spraying technique described in section 4.3.1. The airbrush nozzle was held 150mm away from the painted specimens, with two passes (horizontal movements over the painted surface) being required for each specimen. Each pass was executed in a continuous fashion, where the trigger was depressed for the entire pass duration, and conducted at a speed that resulted in a light coat of droplets on the surface of the specimen (Figure 4.4). Isinglass and Aquazol® 200 were tested at concentrations of 3% in deionised water, 1% in deionised water and 1% in a mixture of Industrial Denatured Alcohol (IDA) and deionised water (one part IDA and three parts water). Similar funori solutions were tested, substituting 3% and 1% concentrations for 0.3% and 0.1% respectively. Concentrations were chosen based on those normally employed by conservators (section 2.3). Funori concentrations were lower than those of the other consolidants as higher concentrations are too viscous to be workable (section 2.3.2). The lower 1% and 0.1% concentrations were chosen to test the theory that more applications of a more dilute solution allows finer control and the avoidance of over-application (section 2.2). Likewise, a proportion of IDA was included in the solutions in order to ascertain if volatile solvents can limit the effect on textile flexibility.

Figure 4.4 – Painted specimen before and after spraying, showing light coat of droplets

Consolidants were maintained at 55ºC throughout application, as isinglass needs to be warm to ensure maintenance of its liquid properties, and it was desirous to employ the same method across the consolidants, although the other consolidants do not require warming. Two passes of the airbrush were required to fully coat each 50 x 50mm specimen. Each combination of consolidant and solution type (henceforth referred to as 'treatment type') was tested with five through fourteen applications (Table 4.1). Each treatment type and application number was carried out on three specimens. Specimens were heat set after each treatment type was applied, using a Willard® miniature lining iron (model M8E) and control unit at 60ºC for one minute (Figure 4.5). Temperature was monitored with a Willard temperature monitor and double-checked on the face of the iron with a re-useable temperature indicator strip. After cooling, specimens were rated on a scale of one to four by lightly drawing a finger over the treated surface and noting the transfer of paint flakes to the finger.

Table 4.1 – Treatment types tested for the consolidation of painted samples

Consolidant	Solution type
Isinglass	3% in deionised water
	1% in deionised water
	1% in IDA and deionised water, 1:3 ratio
Aquazol® 200	3% in water
	1% in deionised water
	1% in IDA and deionised water, 1:3 ratio
Funori	0.3% in deionised water
	0.1% in deionised water
	0.1% in IDA and deionised water, 1:3 ratio

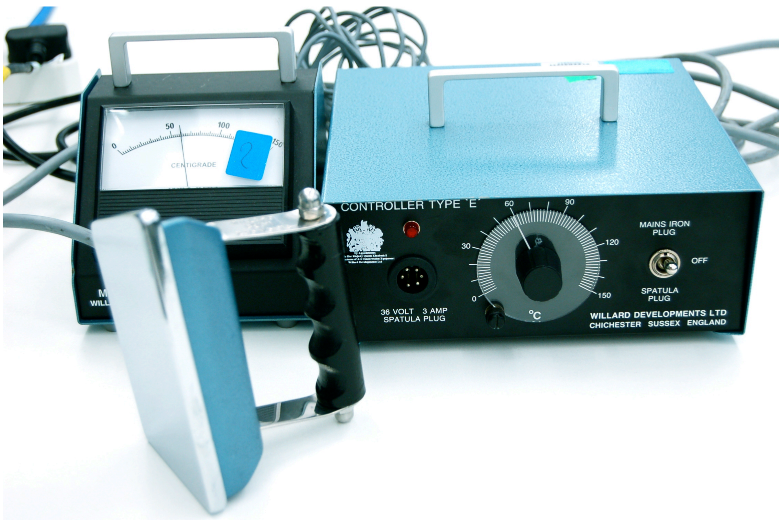

Figure 4.5 – Willard® heating system

4.3.3 Assessment of consolidation success

Consolidation ratings were made by the author alone, as there was insufficient time to perform a more robust sensory analysis. This was sufficient for the means, as the goal of consolidation analysis was to decrease treatment parameters for part two of the investigation. A 'successful consolidation treatment' was classified as an average rating of three or above when the treatment assessment was made (Table 4.2). Average scores for each treatment were calculated from the scores of three specimens and plotted on scatter graphs (Appendix IV). Linear lines of best fit were generated for each treatment type using Microsoft Excel®, and the number of applications at which the line reached a rating of 3 was taken as the minimum number of applications required for successful consolidation (Appendix IV). The lines of best fit provided a consistent way of choosing the number of applications to use for each treatment in section 4.4.

Table 4.2 – Painted sample consolidation ratings

Rating	Definition*
1	Many flakes transferred to finger
2	Some flakes transferred to finger
3	One or two flakes transferred to finger
4	No flakes transferred to finger

*Based on the method of lightly drawing a finger across the consolidated surface and noting the transfer of flakes to the finger.

4.4 Mud-silk testing

The purpose of mud-silk testing was to assess the effect of successful consolidation treatments with a variety of consolidants and solution mixtures on the flexibility of mud-silk. This was performed with the intention of finding treatments that would not perceivably change the flexibility of mud-silk. Flexibility was assessed through instrumental and sensory methods. Initially it was considered that any change in fabric appearance should also be assessed for different treatments, however due to time constraints this was not included in the investigation.

4.4.1 Mud-silk samples

Kjerstin Mackie, textile conservator at the RBCM, was gifted a bolt of mud-silk fabric from a well-travelled friend, who purchased it in China in the 1950s. Kjerstin kindly donated a portion of the un-used fabric to the author for research purposes.

Specimens were cut 200x25mm in size, with ten specimens per treatment type allowed, five with the warp threads following the long edge and five with the weft following the long edge. Specimen shape and size was determined by flexibility test requirements according to BS 3356:1990.[189] No two warp specimens within a treatment set contained the same warp threads, and no two weft specimens contained the same weft threads; in this

[189] British Standards Institution, p2.

way specimens in a set each represented a different part of the fabric as a whole, providing a better representation of fabric properties. Specimens were also staggered as much as possible to avoid the repetition of weft threads in a warp set and warp threads in a weft set, although complete avoidance of repetition was not possible due to the limited fabric available (Figure 4.6). The British Standard did not specify this second insurance of providing representative specimens; therefore it was not imperative that warp specimens had different weft threads, and vice versa. No specimens were cut from within 150mm of the selvedges, in order to avoid distortions from differences in tension affecting flexibility tests. As mud-silk has a water resistant finish, the fabric was scratched before cutting into strips in order to damage the surface enough to allow consolidant penetration similar to that observed in painted samples (Figure 4.7). The degree of scratching necessary was determined experimentally.

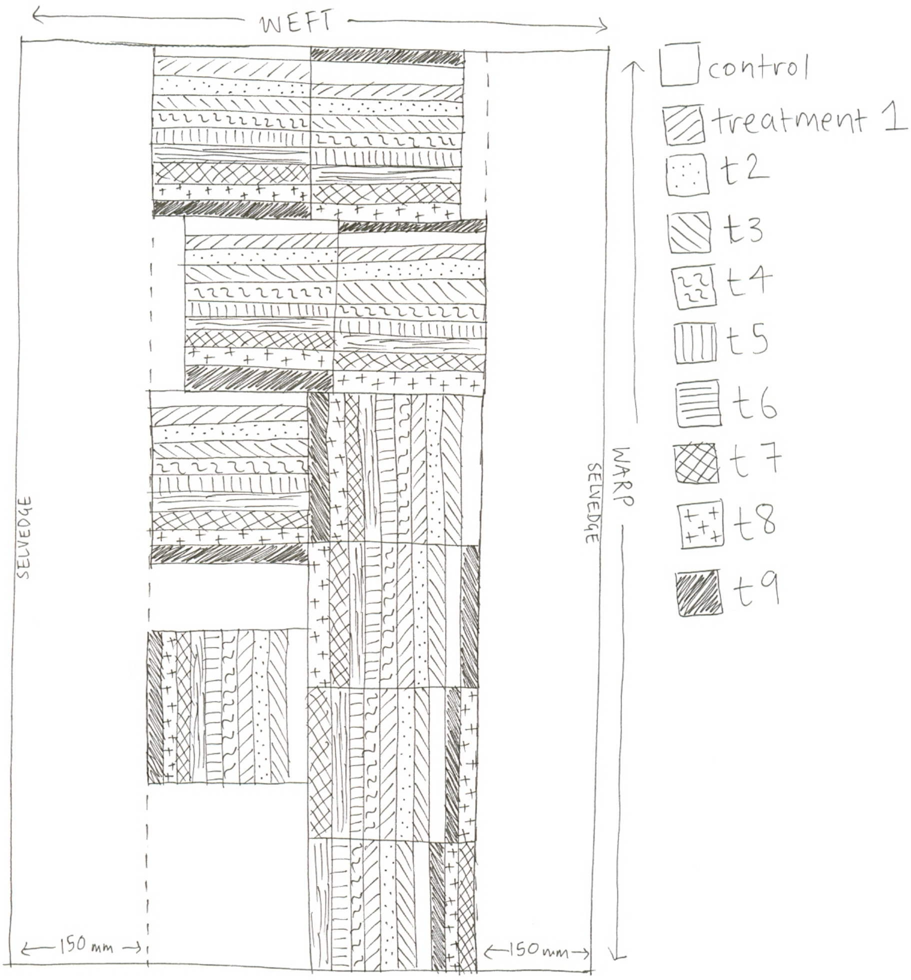

Figure 4.6 – Mud-silk specimen placement

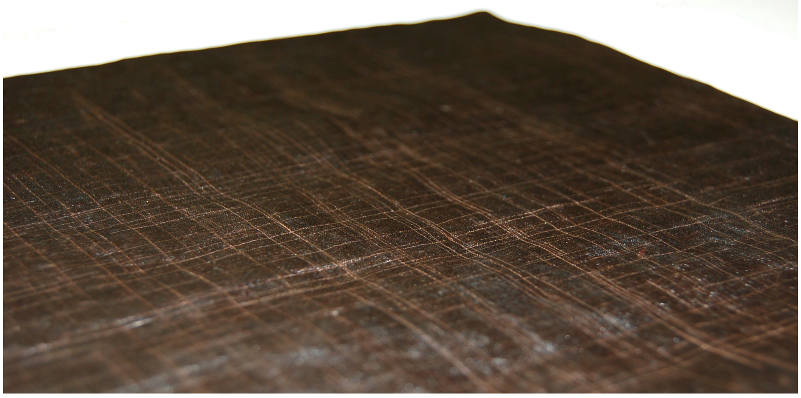

Figure 4.7 – Scratched mud-silk surface allowing consolidant penetration

4.4.2 'Consolidation' of mud-silk

Each treatment type tested in section 4.3.2 was applied to mud-silk specimens, using the average minimum number of applications that provided an acceptable consolidation (sections 4.3.3 and 5.3). The same method was used as for painted sample consolidation, apart from the number of passes per application; since the mud-silk specimens were half as wide as painted specimens, one pass instead of two was necessary per application. The specimens were longer than the iron used for heat setting, so each specimen was heat set in two parts for one minute per part.

4.4.3 Measurement of physical properties

The weight of each specimen was measured before and after treatment with a Sartorius BP150 weighing scale to the nearest milligram.

The average thickness of each specimen after treatment was measured with an electronic micrometer to an accuracy of 10μm by taking an average of three measurements. Thickness was not measured before treatment, as the requisite equipment was not available.

4.4.4 Instrumental flexibility testing

Flexibility testing was undertaken following Peirce's heart-loop method (section 3.3.2). It was not possible to undertake tests using a fixed-angle flexometer, as specimens tended to curl along the warp direction after treatment, especially under low relative humidity (RH). This was only exhibited following consolidation, meaning that specimen length (initially chosen for flexometer tests) could not be optimally chosen. Specimens were conditioned to an RH of 50.5 – 65.9% by placing in a chamber with a manually controlled ultrasonic humidifier attached; however, the temperature was uncontrolled, ranging from 26.0 – 29.5°C. Testing was undertaken in the lab space, which had uncontrolled RH and temperature (38.0 – 50.9%, 25.3 – 28.7°C), with samples only being taken out of the chamber when required for testing. While the chamber provided some buffering against the low RH of the lab space, chamber RH was still variable due to changes in temperature and lab RH. Immediately before testing, a group of specimens were removed from the chamber and prepared for flexibility tests, a process which took approximately 10 minutes. Pieces of card 1 x 2.5cm were attached to each specimen end on the reverse using masking tape, making sure the long edge of each card piece was flush with the short edge of each specimen end (Figure 4.8). Specimen ends were then bent inwards toward the centre of the specimen and clamped together. Bending length, flexural rigidity and bending modulus were calculated (Appendix V).

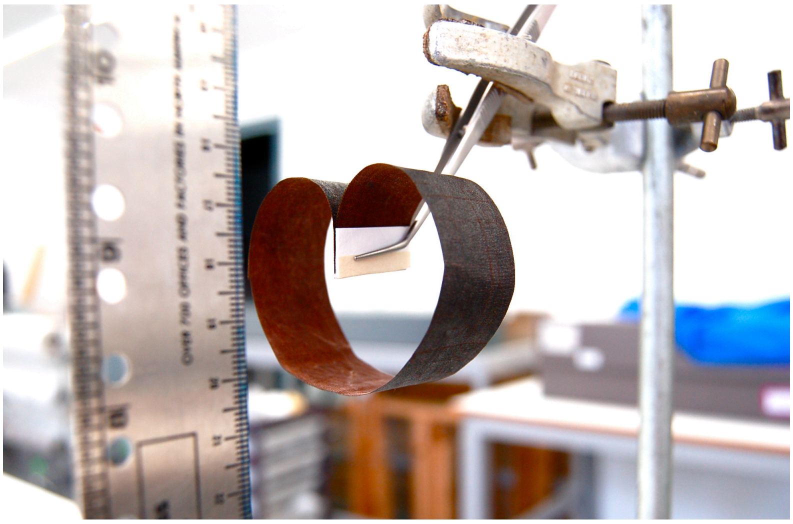

Figure 4.8 – Mud-silk specimen set up for flexibility testing, showing card attached to short ends

4.4.5 Sensory analysis

Sensory analysis was undertaken using Kendall's paired ranking method (section 3.4.1). Seven judges from the University of Glasgow's Textile Conservation course (tutors and students) who were familiar with and regularly handled textiles participated in two 30-minute sessions each on separate days. In a single session a judge assessed one set of warp specimens, followed by one set of weft specimens, with each judge re-assessing the same warp and weft sets on their second session. While there were seven judges, there were only five specimens per treatment type due to a limited supply of mud-silk, meaning that two judges performed their assessments on sets that had already been handled twice by another judge. Each set comprised nine treated samples and one un-treated sample, which produced 45 pairs when paired in every possible way. Each pair was presented to the judges in a random order, with one specimen labelled 'A' and the other labelled 'B'. Specimens within pairs were also randomised from one session to the next. Specimens were conditioned in the humidity chamber and moved into the uncontrolled lab space immediately prior to testing, as in section 4.4.7.

Before starting their first session, judges were asked to read an information sheet and sign a consent form allowing their responses to be included in this report (Appendix VI). The information sheet detailed the purpose of the study, and provided instructions for assessing the flexibility of samples presented. The procedure was also explained verbally, and a demonstration provided. With a pair of specimens side-by-side, orientated vertically, judges were asked to grasp the top of specimen 'A' with the thumb and first two fingers of their dominant hand and bend it towards them and back once only (Figure 4.9). After repeating the procedure with specimen 'B', judges were asked to record which specimen they thought was more flexible, or if they thought the specimens were equal. If necessary, judges were allowed to repeat the procedure as many times as desired, but were encouraged to make a decision with as few repeats as possible. Generally, judges required one execution, and sometimes two or three if the decision was difficult.

Figure 4.9 – Sensory technique for evaluating the flexibility of mud-silk

4.4.6 Statistical analysis

T-tests were undertaken to compare the physical properties and instrumentally measured flexibility of warp and weft specimens, as well as discern the significance of any weight gain in specimens after treatment. Analysis of Variance and post-hoc Tukey tests were undertaken, using the IBM SPSS Statistics computer program, to find significant differences among the physical properties and instrumentally measured flexibility of specimens after treatment.[190] Kendall's coefficient of agreement was calculated to describe inter-judge consistency.

[190] IBM SPSS Version 21.0, IBM®.

CHAPTER 5 RESULTS

5.1 Aerosol application technique:

Aerosol application was found to be effective at applying a controlled volume of consolidant while achieving widespread coverage of the unstable paint surface of painted specimens. The application variables found to influence consolidation were the distance from the nozzle to the treatment surface, pulsed or continuous application, application speed, the use of heat setting, and the number of applications. These techniques were developed using isinglass, however little difference was noted when they were used with other consolidants.

5.1.1 Spray distance

Holding the airbrush 100mm away from the treatment surface or closer meant the droplets had less distance over which to disperse, creating the effect of a denser spray. This resulted in saturation of the textile and pooling of the consolidant on its surface, which was no different to the result of brush application. Additionally, the closer the nozzle was to the textile, the greater the effect of the propelled air stream on loose flakes, resulting in a increasing proportion of flakes being blown away. While holding the airbrush further away from the textile addressed this issue, a distance of 200mm or greater rendered the treatment less effective and the direction of the spray stream less accurate. The mid-way point of 150mm was found to provide an effective treatment with more accurate spraying, while not causing textile saturation or blowing away too many loose flakes.

5.1.2 Pulsed and continuous application

Pulsed application, consisting of short taps on the trigger as the airbrush was passed over the specimen, resulted in better control of the volume of consolidant applied. This was because a smaller amount of consolidant could be applied to a small area, however it was also more difficult to ensure that an even coat was applied. Continuous application, consisting of the trigger being depressed for the entire duration of each pass, allowed greater confidence of an even consolidant coat, thus this method was favoured.

5.1.3 Application speed

The speed at which the airbrush was moved across the treatment surface affected the volume of consolidant applied with each pass, with slower movement increasing the volume and faster movement decreasing it. This variable was difficult to control, and it was found that visual appraisal during application allowed regulation. Experimentation indicated that a light coat of droplets, seen as a slight sheen on the painted surface, was sufficient to result in adequate consolidation (Figure 4.4). While a lighter coat was still acceptable, a coat any heavier than this resulted in pooling of the consolidant and saturation of the textile, rendering the use of aerosol over brush application pointless. In practice, it was only possible to discern the relationship between application speed and volume of consolidant applied by first testing on a piece of tissue or scrap fabric. This was because differences in air pressure from the propellant occurred with changes in temperature or the volume of propellant in the can. This parameter is enormously subjective, and entirely dependent on the operator's experience and perceptions.

5.1.4 Heat setting

When isinglass was used for consolidation, heat setting resulted in a more effective treatment with a lower concentration or fewer applications. Heat setting also appeared to improve consolidation with Aquazol® 200 but not with funori, however this is an anecdotal observation rather than one based on testing.

5.1.5 Number of applications

At least four spray applications of 2% isinglass in deionised water were required to achieve noticeable consolidation with the ideal methodologies identified above. The number of applications required also varied with the degree and type of flaking in painted samples (powdering, tiny flakes, small flakes or larger flakes), as well as the thickness of the paint film.

5.1.6 Other factors

While undertaking consolidation tests with all three consolidants, other factors were identified of which the operator needed to be aware. Firstly, holding the nozzle perpendicular to the treatment surface incurred a risk of solution dripping from the nozzle onto the textile, due to gravity. This risk was higher when solutions with lower viscosity were used. This required the operator to frequently wipe excess solution off the nozzle and be vigilant to avoid dripping solution on the textile. Secondly, holding the fluid reservoir at a 90° angle meant that when the solution level fell below half, the polyethylene tube connected to the nozzle was above the solution. This resulted in air being drawn through the nozzle during spraying, causing spluttering to occur. The solution level therefore had to be periodically topped up to avoid this impacting treatment.

5.2 Treatment codes

As the treatment types applied to painted silk and mud-silk specimens each contained a complex mix of variables, each was given a code to simplify its expression within prose (Table 5.1). The code contains three components, representing the consolidant type (isinglass, Aquazol® 200 or funori), the concentration (3%, 1%, 0.3% or 0.1%) and the solvent (deionised water, or a mix of IDA and deionised water in a ratio of 1:3).

Table 5.1 – Codes used to express specimens treated with different consolidant solutions

Code	Treatment type
C	Control/non-treated specimens
I3_d	Isinglass, 3% in deionised water
I1_d	Isinglass, 1% in deionised water
I1_IDA/d	Isinglass, 1% in IDA:deionised water 1:3
A3_d	Aquazol® 200, 3% in deionised water
A1_d	Aquazol® 200, 1% in deionised water
A1_IDA/d	Aquazol® 200, 1% in IDA:deionised water 1:3
F3_d	Funori, 0.3% in deionised water
F1_d	Funori, 0.1% in deionised water
F1_IDA/d	Funori, 0.1% in IDA:deionised water 1:3

5.3 Painted sample consolidation

Table 5.2 shows the minimum number of applications required by each treatment type to achieve a successful consolidation treatment on the flaky painted silk specimens created. These numbers are taken from the lines of best fit generated for average consolidation ratings (Appendix IV). For Aquazol® 200 and funori, lower concentrations required more applications to achieve the same level of consolidation as higher ones. Conversely, lower concentrations of isinglass required fewer applications than higher ones to achieve successful consolidation. When a proportion of IDA was included in the mixture, isinglass and Aquazol® 200 both required fewer applications than equivalent concentrations in deionised water only, while funori required more.

Table 5.2 – Number of aerosol spray applications of selected consolidant solutions required to achieve a successful consolidation treatment on unstable painted silk

Consolidant solution	Number of applications
Isinglass, 3% in deionised water	13
Isinglass, 1% in deionised water	10
Isinglass, 1% in IDA:deionised water 1:3	8
Aquazol® 200, 3% in deionised water	7
Aquazol® 200, 1% in deionised water	11
Aquazol® 200, 1% in IDA:deionised water 1:3	8
Funori, 3% in deionised water	11
Funori, 1% in deionised water	13
Funori, 1% in IDA:deionised water 1:3	15

5.4 Physical and instrumental measurements

5.4.1 Statistical terminology and notations

This brief description is for the benefit of readers unfamiliar with statistical terminology and notations, allowing the following results to be understood.

Mean (average) values are reported in tables with the standard deviation (SD) in brackets beside them. The SD indicates the dispersion (spread) of the specific samples measured, indicating how variable the group is.[191] Ninety-five percent confidence intervals are also reported, which give the total range within which we are 95% certain that that any measurement could lie.[192] Confidence intervals therefore indicate the range of measurements that may be obtained if the experiment were repeated, while the SD is the actual variation seen in this investigation. The units of SDs and confidence intervals are the same as those of the mean.

Observed differences among the properties of treated specimens are only significant if they are large enough that the difference could not have arisen by natural variability or error. This is expressed by reporting the probability that the observed difference is due to chance. If this probability (p) is less

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[191] Graham Currell and Antony Dowman, *Essential Mathematics and Statistics for Science* (Chichester, Sussex, 2005), p127.

[192] Currell and Dowman, p186.

than or equal to 5%, then the difference is considered statistically significant, and we can say that we are 95% certain that the observed difference is a true one. The notation for this expression is '$p \leq 0.05$', or to convey greater confidence in the difference, '$p \leq 0.01$' or '$p \leq 0.001$'. P-values are reported in brackets to denote the significance level, or footnotes for multiple p-values. P-values were obtained through t-tests and Tukey tests.

5.4.2 Weight and thickness

It was assumed that the weights and thicknesses of warp and weft specimens were equivalent as the fabric tested had a balanced weave. For this reason warp and weft specimen results were combined to give a total sample size of 10 for each treatment group. Table 5.3 shows percentage weight change of specimens after consolidation. T-tests showed that I3_d, A3_d and I1_d specimens were significantly heavier after treatment ($p \leq 0.001$), with a respective percentage weight gain of 4.9%, 2.1% and 0.7%. While the percentage weight change for I1_d specimens was statistically significant, it is unlikely such a small weight gain would cause an appreciable difference in textile flexibility. Other specimen groups exhibited a weight gain, shown by their positive percentage weight changes, however these were not statistically significant due to their variation. This is exhibited by their 95% confidence intervals spanning a percentage weight change of zero. The measured weight of specimens was very variable, in some cases meaning that specimens had a lower measured weight after treatment when compared to before treatment, as indicated by a negative percentage weight change. This shows an apparent insensitivity and fluctuation in the weighing scales used, and indicates that more treatment types may have shown a significant weight gain with more accurate scales.

Table 5.3 – Percentage weight change in mud-silk after consolidation

Treatment	Percentage weight change (%)	
	Mean (SD*†) (n=10)‡	95% Confidence Interval†
Isinglass 3% in deionised water	**4.9 (0.6)**	4.5 – 5.3
Isinglass 1% in deionised water	**0.7 (0.5)**	0.3 – 1.1
Isinglass 1% in IDA:deionised water 1:3	0.1 (3.1)	-2.1 – 2.3
Aquazol® 200, 3% in deionised water	**2.1 (0.8)**	1.5 – 2.7
Aquazol® 200, 1% in deionised water	0.6 (2.4)	-1.1 – 2.3
Aquazol® 200, 1% in IDA:deionised water 1:3	-0.1 (0.9)	-0.8 – 0.6
Funori 0.3% in deionised water	0.4 (0.7)	-0.1 – 0.9
Funori 0.1% in deionised water	0.2 (4.1)	-2.7 – 3.1
Funori 0.1% in IDA:deionised water 1:3	-0.2 (0.7)	-0.7 – 0.3

NB: **Bold typeface** indicates statistical significance ($p \leq 0.001$)

* SD = standard deviation

† units same as for mean

‡ n = number of specimens averaged

Table 5.4 shows the weight per cm^2 of specimens after treatment. Tukey tests showed that I3_d specimens were not significantly heavier than A3_d specimens, but were significantly heavier than all other specimens.[193] Similarly, A3_d specimens were significantly heavier than roughly half of other specimen groups, namely I1_IDA/d, F1_IDA/d, F1_d and C.[194] Tukey tests showed that I3_d specimens were not significantly thicker than A3_d and I1_d specimens, but were significantly thicker than all other treatment groups.[195]

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[193] $p \leq 0.05$ for I1_d; $p \leq 0.01$ for A1_IDA/d; $p \leq 0.001$ for all others.

[194] $p \leq 0.05$ for I1_IDA/d and F1_IDA/d; $p \leq 0.01$ for F1_d; $p \leq 0.01$ for C.

[195] $p \leq 0.05$ for A1_d and $p \leq 0.001$ for all others.

Table 5.4 – Average weight per cm^2 and thickness of mud-silk after consolidation

Treatment	Weight per unit area (mg/cm^2)		Thickness (µm)	
	Mean (SD*†) (n=10)‡	95% Confidence Interval†	Mean (SD*†) (n=10)‡	95% Confidence Interval†
Control	9.4 (0.2)	9.2 – 9.6	154 (11)	149 - 159
Isinglass 3%, in deionised water	**10.0 (0.2)**	9.9 – 10.1	**182 (15)**	176 - 188
Isinglass 1%, in deionised water	9.6 (0.2)	9.5 – 9.7	165 (15)	158 - 172
Isinglass 1%, in IDA:deionised water 1:3	9.5 (0.3)	9.3 – 9.7	158 (25)	152 - 164
Aquazol® 200, 3% in deionised water	**9.8 (0.1)**	9.7 – 9.9	171 (14)	165 - 177
Aquazol® 200, 1% in deionised water	9.5 (0.2)	9.4 – 9.6	160 (12)	155 - 165
Aquazol® 200, 1% in IDA:deionised water 1:3	9.5 (0.3)	9.3 – 9.7	153 (10)	149 - 157
Funori 0.3%, in deionised water	9.5 (0.3)	9.3 – 9.7	153 (9)	148 - 158
Funori 0.1%, in deionised water	9.4 (0.2)	9.2 – 9.6	151 (9)	146 - 156
Funori 0.1%, in IDA:deionised water 1:3	9.4 (0.2)	9.2 – 9.6	151 (9)	146 - 156

NB: **Bold typeface** indicates treatment groups heavier/thicker than groups in regular typeface ($p \leq 0.05$)

* SD = standard deviation

† units same as for mean

‡ n = number of specimens averaged

5.4.3 Bending length, flexural rigidity and bending modulus

T-tests showed that there was no significant difference between the bending lengths of warp and weft specimens, except for controls ($p \leq 0.05$). There was also no significant difference between the flexural rigidities and bending moduli of warp and weft specimens. For this reason subsequent statistical tests were carried out combining warp and weft groups, so that each treatment group had ten specimens. While there was a difference between the bending lengths of control warp and weft specimens, it did not translate into any treated specimens, thus was assumed an anomaly that was magnified due to a small sample size.

Table 5.5 shows the average bending lengths, flexural rigidities and bending moduli of all treatment groups.[196] The only significant difference observed was that I3_d specimens were stiffer than all other treatment groups, indicated by this group's higher average bending length ($p<0.001$). I3_d specimens were still significantly stiffer than all other groups when the effect of weight per cm^2 was removed, as shown by the group's higher average flexural rigidity ($p<0.001$). However, when the effect of thickness was removed, no statistical differences were present among any of the treatment groups. This indicates that the thickness of I3_d specimens contributed substantially to their being stiffer than other treatment groups, while the weight did not.

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[196] NB: Typical values for plain, unfinished calico are, respectively, 2.64cm, 235mg.cm and $87kg/cm^3$, as reported by Peirce, p392.

Table 5.5 – Instrumentally measured bending length, flexural rigidity and bending modulus of mud-silk after consolidation

Treatment code*†‡	Bending length (cm)		Flexural rigidity (mg.cm)		Bending modulus (kg/cm^3)	
	Mean (SD§⁋) (n=10#)	95% Confidence Interval⁋	Mean (SD§⁋) (n=10#)	95% Confidence Interval⁋	Mean (SD§⁋) (n=10#)	95% Confidence Interval⁋
Control	5.34 (0.05)	5.30 – 5.38	1425 (53)	1387 – 1463	4820 (873)	4196 – 5444
I3_d	**6.41 (0.66)**	**5.94 – 6.88**	**2702 (613)**	**1845 – 3559**	5638 (2182)	4079 – 7197
I1_d	5.47 (0.12)	5.38 – 5.56	1575 (121)	1488 – 1662	4389 (1164)	3557 – 5221
I1_IDA/d	5.41 (0.07)	5.36 – 5.46	1496 (99)	1425 – 1567	6767 (6536)	2096 – 11438
F3_d	5.32 (0.04)	5.29 – 5.35	1434 (59)	1392 – 1476	4876 (1001)	4160 – 5592
F1_d	5.32 (0.05)	5.29 – 5.35	1411 (53)	1366 – 1456	5021 (922)	4362 – 5680
F1_IDA/d	5.33 (0.04)	5.30 – 5.38	1432 (53)	1394 – 1470	5065 (1013)	4341 – 5789
A3_d	5.39 (0.08)	5.34 – 5.44	1539 (73)	1487 – 1591	3849 (970)	3210 – 4488
A1_d	5.36 (0.04)	5.33 – 5.39	1471 (52)	1434 – 1508	4411 (971)	3717 – 5105
A1_IDA/d	5.32 (0.05)	5.29 – 5.35	1433 (41)	1404 – 1462	4852 (830)	4259 – 5445

NB: **Bold typeface** indicates statistically larger values ($p<0.001$)

* I = isinglass, A = Aquazol® 200, F = funori

† 3 = 3% for isinglass and Aquazol® 200, 0.3% for funori; 1 = 1% for isinglass and Aquazol® 200 and 0.1% for funori

‡ d = in deionised water, IDA/d = in IDA:deionised water 1:3

§ SD = Standard Deviation

⁋ units same as for mean

n = number of specimens averaged

5.5 Sensory evaluation

A precursory examination of sensory results revealed no apparent difference between ratings for warp and weft specimens. Because of this, and the fact that there was no difference between warp and weft specimens in any instrumental results, each set of results from warp and weft specimens was subsequently treated as separate testing sessions. In this way one session of 30 minutes, in which judges evaluated one warp group and one weft group, effectively became two consecutive sessions with two sets of results. This doubled the sets of results for each judge from two to four. For one judge, a part of their evaluation was compromised, thus their results were excluded from analysis.

5.5.1 Consistency of individual judges

Table 5.6 shows the percentage of answers that were consistently given by each judge out of all the specimen pairs assessed across all sessions. Consistency scores comprised answers where specimens were considered equal, as well as where one specimen was deemed more flexible than the other. 'Complete consistency' was where a judge gave the same answer for a specimen pair in every evaluation session, while 'good consistency' was where a judge gave the same answer three or four times over four sessions. Most judges exhibited complete consistency for approximately half of the specimen pairs. Overall, judges exhibited good consistency for at least 73.3% of specimen pairs, shown by the lowest 'good consistency' score (Table 5.6, Judge 6). This indicates that at least 73.3% of the answers given by judges were repeated at least three out of four times, showing that each judge had relatively consistent opinions.

Table 5.6 – Consistency of six judges over multiple sensory evaluation sessions to rate the flexibility of mud-silk after consolidation

Judge	Answers with complete consistency* (%)	Answers with good consistency† (%)
1	53.3	75.6
2	53.3	86.6
3	57.8	77.8
4	60.0	82.2
5	48.9	84.4
6	48.9	73.3.

* 'Complete consistency' = same answer provided in every evaluation session.

† 'Good consistency' = same answer provided in three or four out of four sessions.

5.5.2 Agreement among different judges

Kendall's coefficient of agreement (u) was calculated using the method described by Kendall,[197] resulting in a value of u=0.62, which was found to be significant (p<0.001) (Appendix VIII). This shows that overall there was good agreement among the judges when one specimen was perceived as

[197] Kendall, pp148-154.

more flexible than the other, however does not account for agreement when judges considered specimens to be equal.

5.5.3 Flexibility scores

The mode (most frequent) answers given by the six judges whose results were analysised are shown in Table 5.7. The table displays the number of judges who thought one specimen group was more flexible, less flexible or equal to other groups.

Overall, I3_d was the least flexible group when compared to all others, exhibited by the fact that I3_d had the lowest total score for the number of times considered more flexible. This can also be seen by looking at the I3_d column in Table 5.7, which shows that judges unanimously considered I3_d specimens to be less flexible than all other groups except A3_d. Four out of six judges considered I3_d specimens less flexible than A3_d specimens, and the remaining two considered them equal. This gave an overall score of five for I3_d being considered less flexible than A3_d. The control group was considered the most flexible, exhibited by it having the highest total score for the number of times considered more flexible.

Table 5.7 – Preferences of six judges when rating the flexibility of mud-silk after selected consolidation treatments

Number of times considered more flexible*†		Number of times considered less flexible*†										Total number of times considered more flexible#
	Treatment‡§⁋	Control	F1_IDA/d	F1_d	F3_d	A1_IDA/d	I1_IDA/d	A1_d	I1_d	A3_d	I3_d	
	Control	-	**3.5 (1)**	**3.5 (1)**	4.5 (3)	5.5 (5)	6	6	6	6	6	47
	F1_IDA/d	**2.5 (0)**	-	**3 (1)**	4.5 (3)	4.5 (3)	5.5 (5)	6	6	6	6	44
	F1_d	**2.5 (0)**	**3 (1)**	-	**3.5 (1)**	4 (2)	5 (4)	6	6	6	6	42
	F3_d	1.5 (0)	1.5 (0)	**2.5 (0)**	-	**3 (0)**	4 (2)	5.5 (0)	6	6	6	36
	A1_IDA_d	0.5 (0)	1.5 (0)	2 (0)	**3 (0)**	-	4.5 (3)	5.5 (5)	6	6	6	35
	I1_IDA_d	0	0.5 (0)	1 (0)	2 (0)	1.5 (0)	-	5 (4)	5 (4)	5.5 (5)	6	26.5
	A1_d	0	0	0	0.5 (0)	0.5 (0)	1 (0)	-	**3.5 (1)**	4 (2)	6	15.5
	I1_d	0	0	0	0	0	1 (0)	**2.5 (0)**	-	**3.5 (1)**	6	13
	A3_d	0	0	0	0	0	0.5 (0)	2 (0)	**2.5 (0)**	-	5 (4)	10
	I3_d	0	0	0	0	0	0	0	0	1 (0)	-	1

NB: **Bold typeface** indicates specimens that were overall considered equal

* For each judge, 1 = more flexible, 0.5 = equal flexibility, 0 = less flexible (total possible score of 6 in each cell)

† Numbers in brackets = number of judges ranking specimen as more or less flexible, as opposed to equal

‡ I = isinglass, A = Aquazol® 200, F = funori

§ 3 = 3% for isinglass and Aquazol® 200, 0.3% for funori; 1 = 1% for isinglass and Aquazol® 200 and 0.1% for funori

⁋ d = in deionised water, IDA/d = in IDA:deionised water 1:3

total possible score 54

F1_IDA/d and F1_d specimens were overall indistinguishable from controls. This is shown by the fact that five out of six judges were unable to say either group was more flexible than the control group. Similarly, other treatment groups that were similar to each other have scores between 2.5 and 3.5 in each cell, indicating that most judges found them to be indistinguishable. In most cases five out of six judges thought the pairs were equal, however all six judges found F3_d and A1_IDA/d to be equal, exhibiting 100% agreement for this pair.

When comparing isinglass-treated specimens with equivalent Aquazol® 200-treated specimens, the latter were accumulatively considered to be more flexible. For example, when comparing I1_IDA/d to A1_IDA/d, the latter group had an accumulative score of 4.5 out of six judges considering it more flexible. This comprised three judges answering that A1_IDA/d was more flexible and three saying the pair was equal. While this is not the majority, the total number of times A1_IDA/d specimens were considered more flexible exceeds that of I1_IDA/d by 8.5, showing that when compared to all other treatments, A1_IDA/d was preferred more often than I1_IDA/d.

In general, treatment types with lower concentrations resulted in more flexible specimens than equivalent treatments with higher concentrations. This is shown by the fact that they have higher scores for the number of times considered more flexible. For example, F1_d and F1_IDA/d groups had higher total scores than F3_d, indicating that judges more often thought they were more flexible than all other groups. Similarly, consolidant solutions made with a proportion of IDA also resulted in specimens with higher total scores than equivalent solutions made with deionised water only, meaning they were overall more flexible.

CHAPTER 6 DISCUSSION

This chapter re-states and discusses each aim presented in the Introduction, also providing general points to consider. The reader is again referred to Table 5.1 for definitions of the codes representing treatment types.

6.1 Aim 1

> Evaluate consolidants commonly used in paintings and textile conservation for their ability to consolidate flaky mud-silk or other textiles with an applied surface film without perceivably altering their flexibility.

As seen by judges' mode sensory evaluation answers, F1_d and F1_IDA/d were the most appropriate treatments for consolidating flaky mud-silk (Table 5.7). This can be seen by the fact that five out of six judges were unable to distinguish between mud-silk treated with these consolidants and non-treated mud-silk. These results are based on 13 and 15 spray applications of F1_d and F1_IDA/d respectively, as dictated by the selection process in section 4.3.3. It must however be noted that the number of applications required for actual flaky mud-silk may vary depending on the degree of flaking and the size of flakes, and as with any treatment the conservator's own discretion must be used.

As discussed in section 2.3, funori tends to be an overlooked consolidant in the field of textile conservation, while isinglass is commonly used. Isinglass is in reality a poor choice when consolidating fine textiles that must retain their flexibility, as seen by both instrumental and sensory evaluation results. This is exhibited by the fact that I3_d was the only treatment that resulted in mud-silk specimens being significantly stiffer when measured using Peirce's heart-loop method (Table 5.5). This is also exhibited by all judges perceiving isinglass-treated mud-silk as being less flexible than non-treated mud-silk in sensory evaluation tests (Table 5.7). Judges thought this of isinglass even at a concentration as low as 1% and when techniques were employed to limit consolidant penetration, such as spray application and mixing in a proportion of volatile solvent. That judges always thought I3_d specimens were less flexible than all other treatment groups indicates the total inappropriateness of this particular treatment option, which is reinforced by the instrumental results. Conversely, funori is an excellent consolidant for fine textiles, exhibited by judges finding it difficult to perceive a difference between funoi-treated and non-treated mud-silk, as discussed above. Due to the lower adhesive strength of 0.1% funori compared to 1% isinglass, more applications were required to achieve the same level of consolidation for painted textile specimens. Even though funori and isinglass solutions were not directly comparable, the resulting treatments were theoretically equivalent in terms of their adhesive strength, meaning that the funori treatments can still be considered superior when assessing their effect on textile flexibility. The higher number of applications needed with funori solutions increased the time required for treatment. If a longer treatment time were undesirable, this could be addressed by adding a small proportion of isinglass to funori (a practice not unprecedented), which would increase the adhesive strength while maintaining funori's other desirable properties.[198] This would require more testing to find a desirable mixture.

While Aquazol® 200-treated specimens were far from equal in flexibility to non-treated specimens, showing the treatments to be poor choices, results showed that Aquazol® 200 affected the flexibility of mud-silk less than equivalent isinglass treatments (section 5.5.3). It may therefore be possible to achieve an appropriate treatment with Aquazol® 50 (which has a lower molecular weight), or some combination of the different grades. Again, more testing would be required to ascertain appropriate options. Both isinglass and Aquazol® may also provide appropriate consolidation treatments for fine textiles if concentrations lower than 1% are used, however this would require more applications to achieve the same adhesive strength.

198 Masson and Ritter, pp94-95.

6.2 Aim 2

Explore theories discussed in paintings and painted textile conservation literature asserting that manipulating consolidant solution properties can control its penetration into the paint or surface film and textile of paintings and painted textiles, and by extension its effect on the textile's flexibility.

Sensory evaluation results indicated that using lower concentrations and incorporating a volatile solvent (IDA) both decreased the effect treatments had on the flexibility of mud-silk, as seen by the total number of times respective treatments were considered more flexible than all others (section 5.5.3). This was consistent across all three consolidants, supporting ideas that lower concentration and higher volatility of solutions can help to decrease the penetration of the consolidant into the paint or surface film and textile, and therefore decrease the effect on textile flexibility (section 2.2.4).

Although section 2.2 theorised that increased penetration results in decreased flexibility of textiles, results indicate the relationship may not be so simple. As shown in section 5.4, I3_d specimens were significantly less flexible than all other groups because of their thickness. While A3_d and I3_d specimens were statistically no different in terms of weight, I3_d specimens were significantly thicker than A3_d specimens. The only difference between these two treatments, aside from the consolidant type, was the number of applications; I3_d required thirteen applications to achieve successful consolidation on painted specimens, while A3_d only required seven (Table 5.2). This explains the difference in thickness, as I3_d specimens had a greater quantity of consolidant present, however it also points towards an appreciable difference in the physical properties of each solution. Since I3_d required more applications, it is likely that the solution was not penetrating the paint and textile as much as A3_d before drying, meaning more applications were required to achieve good cohesion within the paint and good adhesion between the paint and textile. One explanation is that I3_d was more viscous than A3_d, causing it to move more slowly and penetrate less. It is also possible that the polymers in I3_d were larger than those in A3_d causing lower penetration, similar to observations with different molecular weights of Aquazol®.[199] In either case, the physical properties of the solution affected its ability to penetrate specimens, which in this case caused them to become less flexible than A3_d specimens because of the number of applications required. This indicates that there is a complex relationship between the number of applications required and properties such as consolidant type, adhesive strength, viscosity, concentration and volatility.

[199] Arslanoglu, p10.

6.3 Aim 3

> Develop and explore the use of an aerosol spraying technique for consolidant application to textiles, and discuss the merits and drawbacks of the technique.

Through the tests carried out with isinglass on painted silk samples, a suitable aerosol application technique was developed for consolidation treatments. The most obvious advantage of aerosol application over brush application, alongside other misting techniques, is that it covers the surface to be consolidated with a fine coat of droplets (if appropriate parameters are used) rather than saturating the textile. This affords greater control over the volume of consolidant applied, regulating over-application. Aerosol application allows for good directional control of consolidant droplets, as opposed to medical nebulisers and ultrasonic misters, which produce droplet clouds that are more widely dispersed.[200] This property would be particularly advantageous when treating three-dimensional textiles, especially where small areas are to be treated, as it allows a more targeted treatment. Unfortunately, the air pressure providing directionality also has the potential to blow away loose flakes of the film in need of consolidation, depending on the spray distance employed (section 5.2.1). For some objects this may not be an issue, however in other objects the film may be too unstable to risk this particular method. Aerosol systems also utilise smaller volumes of liquid, which is an economical advantage if treating a small

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[200] McLeod, p20

object or area. It follows that if a large object is to be treated, an aerosol system may not be as practical as other misting methods, as the fluid reservoir may need to be topped up too frequently.

It was found that controlling the consistency of application was difficult, and there was a risk of dripping. Application consistency depended on a number of factors, including the use of pulsed versus continuous application, application speed, and the pressure of the compressed propellant in its can (section 5.2.2). While continuous application allowed for greater consistency, application speed was entirely dependent on the operator. This may be viewed as disadvantageous if the operator is inconsistent, however with good control can be turned into an advantage to compensate for changes in air pressure from varying temperature or volume of propellant in the can. While dependent on the operator, the technique is not necessarily less consistent than brush application. Most techniques employed in conservation are dependent on the skill and training of the conservator, and as with any technique aerosol application can be learned and practiced. Conversely, the risk of dripping was not caused by operator inconsistencies, but a result of holding the airbrush at a 90º angle to the horizontal table. Dripping could result in adverse effects on an object, such as tide lines or displacement of unattached film particles.[201] This specific risk is connected with spraying on a horizontal plane, and if the treatment were carried out on a garment whilst on a mannequin, there would be little risk of dripping. It

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[201] Wild, p52

should also be noted that if an internal-mix airbrush were used instead of an external one there would be no risk of dripping, as the only liquid outside the system is that propelled in the form of droplets.

Use of the aerosol system with IDA meant that adequate health and safety precautions were necessary, which may make one-off use of the technique impractical for some conservators. In this case, the particular room worked in did not have fume extraction, thus a mask with an adequate filtration system was worn. This increased the fatigue of the operator, necessitating more frequent breaks. The cost of personal protective equipment should be factored into any treatments proposed with this method. Since all the consolidants used were non-toxic, no ventilation equipment was necessary for solutions made with deionised water only, however if more toxic consolidants are used with the technique safety of the operator should be considered.

6.4 General considerations

As funori was used at lower concentrations than isinglass and Aquazol® 200 due to workability issues, it should be kept in mind that results from funori are not directly comparable to those from isinglass and Aquazol® 200. The method attempted to eliminate any variability caused by the adhesive strength of the respective concentrations by using an appropriate number of applications (section 4.3.3). However, as seen in section 6.2, the relationship between consolidant and concentration is also affected by other factors such as viscosity, therefore adjusting the number of applications is not a fail-safe.

Normal practice for instrumental and sensory evaluation involves the use of a standard test environment, as it is known that relative humidity affects the physical properties of textiles. The test space for this investigation was uncontrolled, which may have caused varying flexibility among specimens. This could have contributed to the variability observed in instrumental tests, as well as intra- and inter-judge inconsistencies in sensory evaluation results.

While initially instrumental flexibility tests were predicted to be more sensitive and reliable than sensory evaluation, results showed that the latter was able to provide greater discrimination among treatment groups. Instrumental results were only able to discern that I3_d specimens were stiffer than all other specimens, both treated and non-treated, with there being no significant difference among any other groups (Table 5.5). This could partly be attributed to the small sample size, however it appears that the differences in flexibility were too subtle for the heart-loop method to discern. Sensory evaluation was able to show that experts judged most consolidation treatments as rendering mud-silk less flexible than non-treated mud-silk. This reveals that where small differences in flexibility are concerned, textile conservators appear to be more sensitive than Peirce's heart-loop test.

Retrospectively, the sensory evaluation results show limitations in the method that were not apparent when it was developed. For example, the small number of judges meant that it was difficult to determine clear opinions regarding the flexibility of similar specimens. This is shown by the fact that for some pairs, half of the judges considered the specimens equal while the other half considered one specimen more flexible (e.g., I1_IDA/d versus A1_IDA/d, section 5.5.3). With more judges, there may have been a clear preference, indicating whether the two were really considered different or not. Another example is that it was difficult to distinguish between inconsistent behaviour and judges truly not being able to discern between specimens. This may have been less of an issue if a rating scale had been used instead of paired ranking, as judges would not have chosen one specimen over the other to 'please the experimenter' (section 3.4.1). Despite the limitations of the method, the results obtained are still useful and provide a foundation on which more targeted studies can be built, however the limitations should be kept in mind when interpreting results.

CHAPTER 7 CONCLUSION

7.1 Main findings

Of the consolidants, concentrations and solvent mixtures investigated, funori 0.1% in deionised water and IDA:deionised water 1:3 were clearly the best candidates to treat flaky mud-silk or unstable fine painted textiles, as these treatments rendered mud-silk near indistinguishable from non-treated mud-silk in terms of flexibility. While isinglass is a consolidant commonly employed by textile conservators, results indicated that funori is more appropriate for treating textiles that must retain their flexibility. This conclusion allows conservators to base their consolidant choice on firm data, rather than past or common practices.

Exploration of the effect of solution properties, such as volatility and viscosity, on textile flexibility showed that their manipulation allows fine control of the consolidation treatment. For example, the viscosity of isinglass was seen to affect its penetration and consolidation power, thus affecting the number of applications required and the stiffening effect on textiles. If anything, attempts to meet Aim 2 generated more questions than answers regarding the treatment factors affecting textile flexibility.

The investigation of aerosol application parameters showed that while the method has limitations, it is a valid and useful technique. As with any method, practice is required to attain a good skill level, but overall, aerosol application can be a good choice for consolidating small or three-dimensional textiles.

7.2 Future research

Because of the complexity of the relationships among all the parameters affecting consolidation treatments, the results found in this investigation are only the tip of the iceberg. While this investigation showed that isinglass and Aquazol® 200 were not appropriate consolidants for fine textiles at the concentrations tested, using lower concentrations with more applications may be appropriate. It is also possible that mixing different consolidants could result in an appropriate treatment, an option that was outside the scope of this investigation. More research is warranted in these areas. It was obvious that consolidant type, concentration, viscosity, volatility and number of applications all interact in specific ways to affect the flexibility of a consolidated textile, however these relationships are still little understood. Can *any* consolidant be manipulated to produce an appropriate treatment? What combinations are most practical in terms of health and safety, treatment time, and cost? Futher research could answer these and other questions about how conservators can exploit the interactions of consolidant properties.

7.3 Overall summary

While it is possible to achieve adequate treatments with recipes and methods that have been tried and tested, this investigation has shown that there is a great potential to control consolidation treatments by manipulating their parameters. By understanding the materials they are using and how they interact, conservators have the power to improve conservation practices, and apply more creative and aesthetically appropriate treatments than in the past. This innovation in thinking has marked the field of conservation since its inception, and is what allows conservators to prolong the life of objects and maximise the study and enjoyment of them. By building on tried and tested methods reported by paintings and textile conservators, this project investigated and developed a treatment strategy that would be appropriate for the conservation of flaky mud-silk. The treatment was shown to minimally affect the flexibility of mud-silk, and while the number of applications needed to stabilise flaky mud-silk may vary from that used in this investigation, it has been shown that a treatment can be applied that will not compromise the textile's visual integrity. This would allow objects such as the RBCM jacket to fulfil their research and display potential, without changing the information communicated or the visual impression. Overall, the investigation has provided useful and practical information for conservators wishing to consolidate flaky mud-silk or fine painted three-dimensional textiles.

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APPENDICES

Appendix I Materials and Suppliers

Kremer Iron Oxide Black: AP Fitzpatrick Fine Art Materials (http://shop.apfitzpatrick.co.uk)

Isinglass: Talas (http://www.talasonline.com)

Aquazol 200®: Talas (http://www.talasonline.com)

Funori: Talas (http://www.talasonline.com)

Appendix II Preparation of consolidants

Isinglass

Isinglass was cut into small pieces, and then processed into fine fibres using an electric coffee grinder (Figure II.A). Three grams or one gram were covered with 100mL of deionised water for 3% and 1% solutions respectively. One gram was covered with 75mL of deionised water for the IDA solution. The solutions were left to soak overnight to rehydrate and partially solubilise the isinglass. Beakers containing isinglass solutions were placed into a water bath and the temperature was raised to 60°C within 30 minutes while stirring to fully solubilise the protein. Each solution was strained through two layers of muslin to remove insoluble components before using. After straining, 25mL of IDA was added to the 75mL solution. This was added immediately before use to avoid excess evaporation of IDA.

Figure II.A – Ground and un-ground dried isinglass

Funori

Funori was cut into small pieces, and three grams soaked in 100mL of deionised water overnight to rehydrate and partially solubilise (Figure II.B). The 3% solution was warmed to 60ºC to better solubilise, however still remained extremely viscous and glutinous, so was diluted to 1% by adding 200mL of deionised water. The solution was strained through two layers of muslin to remove insoluble components and stored in a refrigerator for future use (Figure II.C).

To make up 0.3% and 0.1% solutions, 30mL and 10mL respectively of the 1% funori solution were measured out and brought up to 100mL with deionised water. Solutions were warmed to 60ºC before use. To make up the 0.1% IDA solution, 10mL of 1% funori was brought up to 75mL with deionised water and 25mL of IDA added after warming.

Figure II.B – Dried funori

Figure II.C – Straining funori through muslin

Aquazol® 200

Three grams and one gram of Aquazol crystals (Figure II.D) were weighed out and covered with 100mL of deionised water for 3% and 1% solutions respectively. Solutions left and stirred occasionally until crystals were solubilised, approximately one hour, then warmed to 60ºC before use. To make up the IDA solution, one gram of Aquazol was dissolved in 75mL of deionised water, and 25mL of IDA added after warming.

Figure II.D – Aquazol® 200 crystals

Appendix III Risk assessment and COSHH forms

University of Glasgow

RISK ASSESSMENT FORM

School: Culture and Creative Arts	**Section:** Centre For Textile Conservation and Technical Art History	**Location:** Room number(s) 309A, 309B, 314, 315	**Reference No:** R21/13	**Related COSHH Form (if applicable):** C103/13, C104/13, C110/13

Description of activity:
Enzyme treatment with α-amylase and buffer
Consolidating fabrics with adhesives
Use of volatile solvents

Persons at risk:
Student undertaking treatments

Is operator training/supervision required? If yes, please specify:
No

Hazards/ Risks	Current controls	Are these adequate?	What action is required if not adequately controlled?
Spillage of liquids onto surfaces	Have stoppered flasks. Have towels and paper towels to mop up spills.	Yes	
Breathing in powders and fumes	Wear PPE, use appropriate extraction if necessary	No	COSHH form required
Spillage of chemicals on hands	Be cautious when decanting liquids	Yes	
Burning with hot water	Wear PPE, be cautious when moving containers	Yes	
Broken glass	Be careful when moving glassware. Have dustpan and brush for cleaning up and broken glass container to hand	Yes	
Burning with hot iron	Be careful of hot surfaces, put sign next to iron when unattended	Yes	

Completed by (print name and position, and sign):	**Kate Blair** (signature)	**Date:** **15th May 2013**
Approved by (print name and position, and sign):	**Karen Thompson** (signature)	**Date: 15.5.13**

COSHH Assessment Form

University of Glasgow

School: Culture and Creative Arts **Title of Project:** Dissertation	File ref: C103/13 Date:08/08/13

Room No.	315	**Persons involved:**	Student undertaking treatment
Building:	Robertson		

Description of procedure: Treatment of fabric samples to soften/remove starch deposits

Substance used	Quantities used	Frequency of use	Hazards identified	Exposure route
α-amylase, from Bacillus sp.	1g	One day	R42 – Avoid breathing in dust	May cause sensitisation by inhalation

Could a less hazardous substance (or form of the substance) be used instead ? **No**

Justify not using it: Required to break down starch

What measures have you taken to control risk?

Engineering controls:
Glass cover employed when measuring out powder

PPE:
Dust mask, gloves, safety glasses, lab coat.

Management measures:
Stored in chemicals refrigerator. Tutor present.

Checks on control measures:
Tutor

Is health surveillance required? **No**

Training requirements:
None

Emergency procedures:
Inhalation: Move to fresh air. If breathing difficult, get medical assistance
Skin contact: Wash with soap and plenty of water. Consult a doctor.
Eye contact: Rinse with water for at least 15mins or use eye wash station. Consult a doctor
Ingestion: Rinse mouth with water (if conscious). Consult a doctor

Waste disposal:
Do not let enter drains unless denatured

For small quantities, denature by mixing with 0.01% acetic acid then rinse with copious amounts of water down sink.

For large quantities use waste disposal service.

Name and position of assessor:	Kate Blair, student	**Signature**:	K Blair
Name of supervisor (student work only):	Karen Thompson, tutor	**Signature**:	Karen Thompson
Name of Head of School or nominee:		**Signature**:	

COSHH Assessment Form

University of Glasgow

School: Culture and Creative Arts **Title of Project:** Dissertation	File ref: C104/13 Date: 08/08/13

Room No.	315	**Persons involved:**	Student undertaking treatment
Building:	Robertson		

Description of procedure: Consolidation of fabric samples

Substance used	Quantities used	Frequency of use	Hazards identified	Exposure route
Aquazol® 200, poly(2-ethyl-2-oxazoline) - powder	≤3g	Two days a week for three weeks	Not hazardous according to EC regulations	Respiratory system Skin Ingestion Eyes

Could a less hazardous substance (or form of the substance) be used instead ? **No**

Justify not using it: Required for treatment

What measures have you taken to control risk?

Engineering controls:
Use in well ventilated area

PPE:
Gloves, safety glasses, lab coat

Management measures:
Tutor present

Checks on control measures:
Tutor

Is health surveillance required? **No**

Training requirements:
None

Emergency procedures:
Inhalation: Move to fresh air
Skin contact: Wash with soap and plenty of water
Eye contact: Rinse immediately with plenty of water
Ingestion: Do not induce vomiting; slowly dilute with 1-2 glasses of water or milk and seek medical attention

Waste disposal:
If dissolved in water, flush down sink with copious amounts of water.

If dissolved in other solvent, place in the appropriate waste container (chlorinated or non-chlorinated solvent waste).

Name and position of assessor:	Kate Blair, student	**Signature**:	[signature]
Name of supervisor (student work only):	Karen Thompson, tutor	**Signature**:	[signature]

COSHH Assessment Form

School: Culture and Creative Arts **Title of Project:** Dissertation	File ref: C110/13 Date: 08/08/13

Room No.	315	**Persons involved:**	Student undertaking treatment
Building:	Robertson		
Description of procedure:	Consolidation of fabric samples		

Substance used	Quantities used	Frequency of use	Hazards identified	Exposure route
Industrial Denatured Alcohol	25mL	Twice a day, two days a week for three weeks	R11 – Highly flammable R20/21/22 – Harmful by inhalation, skin contact and swallowing R68/20/21/22 – Risk of irreversible effects through inhalation, skin contact and swallowing	Respiratory system Skin Ingestion Eyes

Could a less hazardous substance (or form of the substance) be used instead ? **No**

Justify not using it: Required for treatment

What measures have you taken to control risk?

Engineering controls:

PPE:
Mask with appropriate filtering system, gloves, safety glasses, lab coat.

Management measures:
Stored in chemical cupboard. Tutor present.

Checks on control measures:
Tutor

Is health surveillance required?	**No**	**Training requirements:** None

Emergency procedures:
Inhalation: Move to fresh air. If breathing difficult, give oxygen
Skin contact: Wash immediately with plenty of water for at least 15 mins. Immediate medical attention. Wash clothing before reuse.
Eye contact: Rinse immediately with water, also under eyelids for at least 15mins or use eye wash station. Immediate medical attention required.
Ingestion: Call doctor or poison control centre immediately. Do not induce vomiting

Waste disposal:
Place in non-chlorinated solvent waste.

NB log amount of solvent used.

Name and position of assessor:	Kate Blair, student	**Signature**:	[signature]
Name of supervisor (student work only):	Karen Thompson, tutor	**Signature**:	[signature]

Appendix IV Painted sample consolidation results

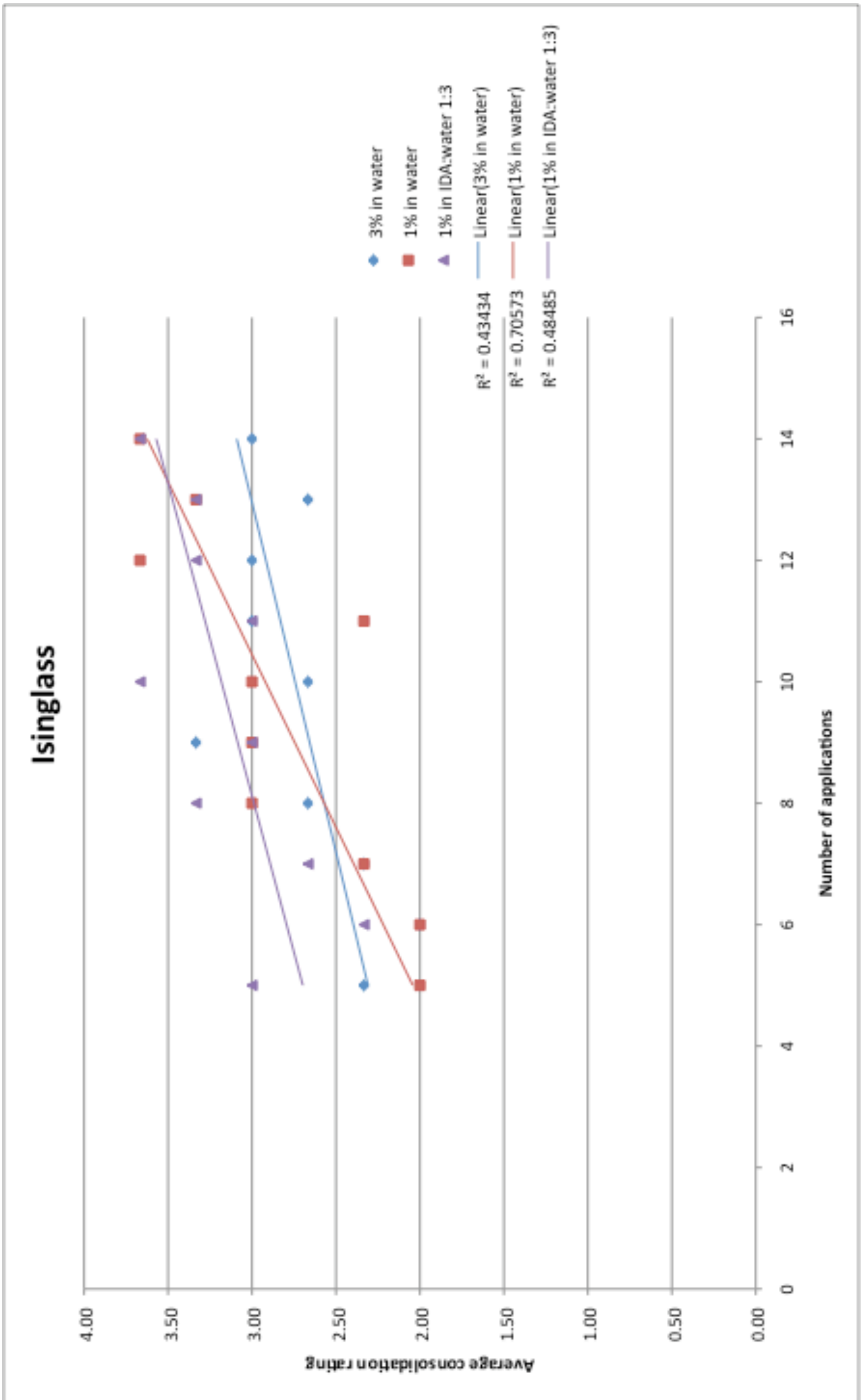
Consolidation ratings

Treatment*	Number of applications									
	5	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
I3_d	2	2	2	2	3	3	2	3	3	3
	2	3	2	4	4	3	3	3	3	3
	3	1	3	2	3	2	4	3	2	3
I1_d	2	2	2	3	4	3	2	4	3	3
	2	2	3	2	3	3	3	3	3	4
	2	2	2	4	2	3	2	4	4	4
I1_IDA/d	2	2	2	3	4	3	3	3	4	4
	3	2	2	3	2	4	3	3	3	4
	4	3	4	4	3	4	3	4	3	3
A3_d	3	3	3	3	3	4	4	4	3	3
	3	3	3	3	4	3	3	3	2	4
	2	2	3	3	4	3	4	3	3	4
A1_d	3	2	3	3	3	3	3	3	3	4
	2	3	3	2	3	3	3	3	3	3
	2	2	3	2	4	3	3	3	3	3
A1_IDA/d	2	2	3	3	4	2	4	4	4	4
	3	3	3	3	3	3	3	3	3	3
	3	3	3	2	3	4	3	3	3	4
F3_d	3	3	2	2	2	3	3	3	3	4
	3	2	2	3	3	3	3	2	3	3
	3	3	3	3	3	4	3	4	3	3
F1_d	2	2	2	2	2	2	3	2	2	2
	3	2	2	2	2	3	3	2	2	2
	2	2	2	3	3	3	3	2	2	2
F1_IDA/d	2	2	2	3	2	3	2	2	2	3
	2	2	2	2	2	3	2	2	3	3
	2	2	2	2	3	4	3	3	3	3

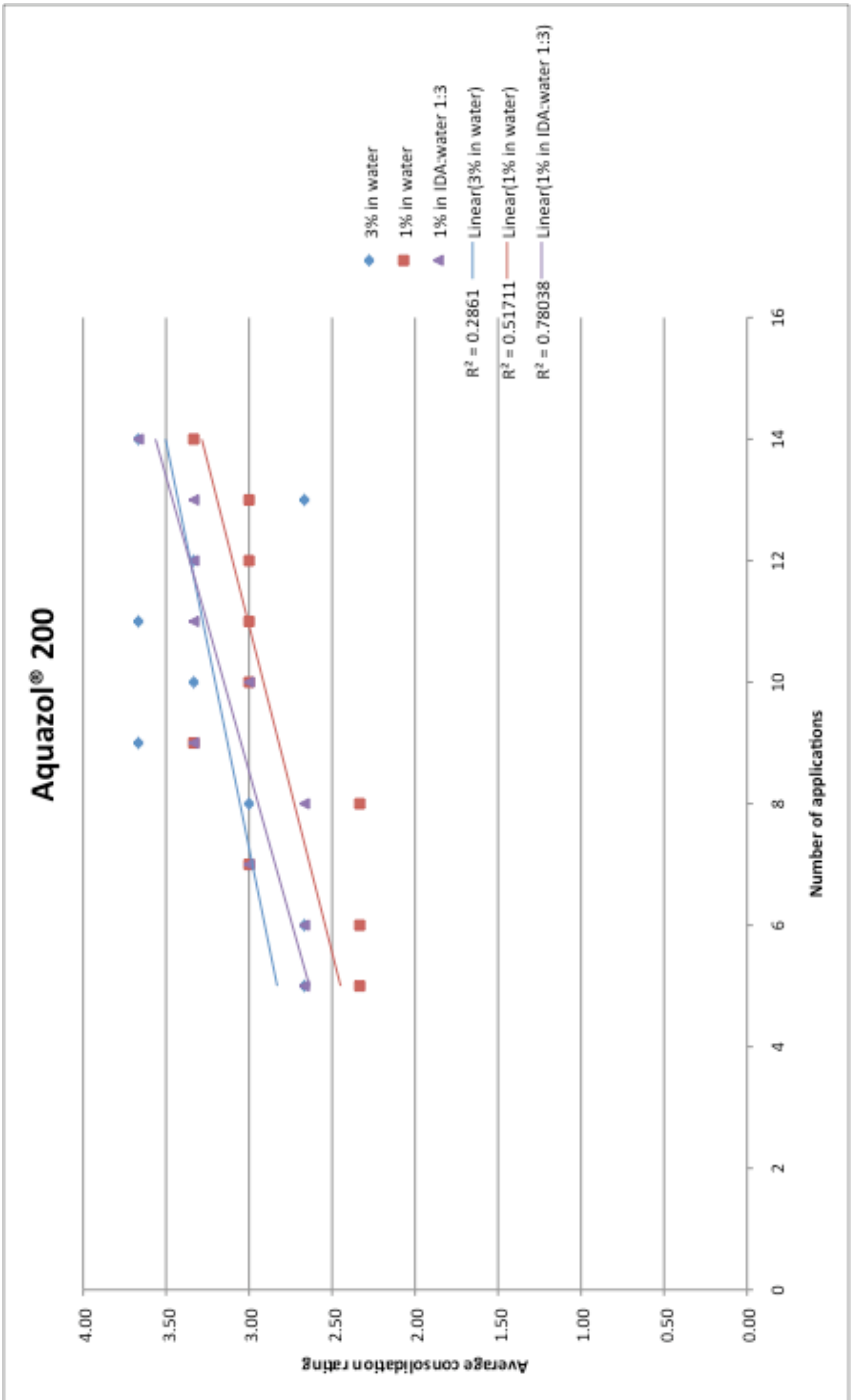
NB: Each consolidant solution was applied to three specimens for each application number

* See Table 5.1 for definitions of codes

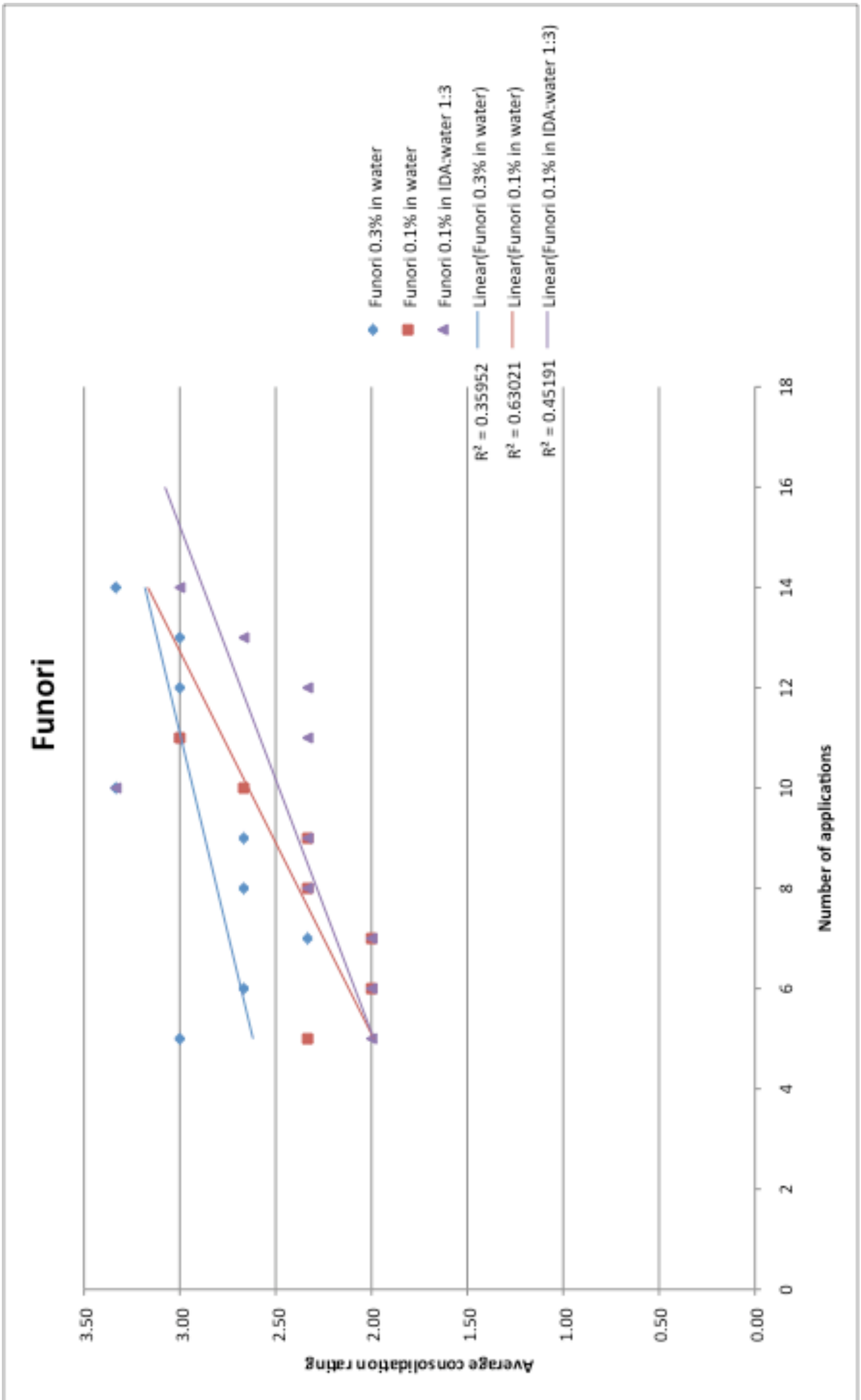
Scatter graph showing lines of best fit for isinglass treatments



Scatter graph showing lines of best fit for Aquazol® 200 treatments



Scatter graph showing lines of best fit for funori treatments



Appendix V Equations for Peirce's heart-loop method

Bending length (c):

Peirce's equation for bending length is: $\mathbf{c = l.f_2\theta}$

Where: $\mathbf{f_2\theta} = (\cos\theta/\tan\theta)^{1/3}$

$\boldsymbol{\theta} = 32.85^o.d/l_0$

$\mathbf{d} = l - l_0$

$\mathbf{l_0} = 0.1337L$

$\mathbf{l}$ = loop extent (measured width of loop, see Figure 3.2)

$\mathbf{L}$ = length of specimen, excluding clamped portion

Worked example:

A specimen has a loop extent (l) of 3.5 cm and length (L) of 18.0 cm

$l_0 = 0.1337 \times 18.0$ cm
$= 2.41$ cm

$d = 3.5$ cm $- 2.41$ cm
$= 1.09$ cm

$\theta = 32.85^o \times (1.09 \text{ cm}/2.41 \text{ cm})$
$= 14.86^o$

$f_2\theta = (\cos 14.86^o/\tan 14.86^o)^{1/3}$
$= 1.54$

$c = 3.5$ cm $\times 1.54$

c = 5.38 cm

NB: When calculating $f_2\theta$ the units must be in degrees not radians

Flexural rigidity (G)

Flexural rigidity is calculated by: **$G = wc^3$**

Where: **w** = weight per unit area (mg/cm^2)

c = bending length (cm), as calculated above

Worked example:

A specimen has a weight per unit area (w) of 9.1 mg/cm^2 and a bending length (c) of 5.38 cm.

G = 9.1 mg/cm^2 x 5.38^{3}cm

G = 1417 mg.cm

Bending modulus (q)

Bending modulus is calculated by: **$q = 12G.10^6/d^3$**

Where: G = flexural rigidity (mg.cm), as calculated above

d = thickness of specimen (μm)

Worked example:

A specimen has a flexural rigidity (G) of 1417 mg.cm and a thickness (d) of 147 μm.

q = (12 x 1417 mg.cm x 10^6)/147^3μm

q = 5342 kg/cm^3

Appendix VI Sensory evaluation material for participants

Sensory information sheet

THE FLEXIBILITY OF FABRIC AFTER CONSOLIDATION TREATMENTS

Purpose:

The current investigation aims to evaluate the effect of a range of consolidation treatments on the flexibility of a fabric with a damaged surface coating.

Scope:

The project is investigating three different consolidants: Isinglass, funori and Aquazol® 200. Each consolidant has been mixed using three different recipes incorporating different concentrations and solvents, giving a total of nine consolidation treatments investigated. The success of the treatments is not being assessed, only their effect on the flexibility of the fabric to which they are applied.

Instructions for analysis:

Consolidation treatments have been applied to 20 x 2.5cm fabric strips. Some samples have the warp threads following the long edge, and others have the wefts following the long edge. You will first assess either the warp or the weft group, followed by the remaining group.

Samples will be presented in pairs. With each pair presented, you are asked to make a judgement concerning the flexibility of the samples, and rank each sample compared to the other in its pair. On your evaluation sheet, circle the sample in the pair that is the most flexible of the two, or if they are equal write '='. Each pair should take between 15 – 20 seconds to evaluate, with the entire session lasting a maximum of 30 minutes.

You will complete two sessions in total, each on a separate day.

<u>Method for flexibility judgement:</u>

Grasp the top of the strip between the thumb and first two fingers of your dominant hand. Bend the strip end in towards the centre of the strip and back one time. Repeat with the other strip in the pair, and judge which strip is more flexible.

You may repeat the procedure if required, however you are encouraged to make a judgement with as few repeats as possible.

Consent form

CONSENT TO THE USE OF DATA
University of Glasgow, College of Arts Research Ethics Committee

I understand that Kate Blair is collecting data in the form of ranked opinions for use in an academic research project at the University of Glasgow.

I confirm that I have read the attached information sheet describing the purpose, scope and method of the investigation.

I give my consent to the use of data for this purpose on the understanding that:

- All names and other material likely to identify individuals will be anonymised.
- The material will be retained in secure storage for use in future academic research
- The material will be used in future publications, both print and online.

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Appendix VII Sensory evaluation results

Judge 1

	Session			
A/B	1	2	3	4
I3/I1	I1	I1	I1	I1
I3/IE	IE	IE	IE	IE
I3/F3	F3	F3	F3	F3
I3/F1	F1	F1	F1	F1
I3/FE	FE	FE	FE	FE
I3/A3	A3	A3	A3	A3
I3/A1	A1	A1	A1	A1
I3/AE	AE	AE	AE	AE
I3/C	C	C	C	C
I1/IE	IE	=	I1	=
I1/F3	F3	F3	F3	F3
I1/F1	F1	F1	F1	F1
I1/FE	FE	FE	FE	FE
I1/A3	I1	=	I1	=
I1/A1	=	I1	A1	I1
I1/AE	AE	AE	=	AE
I1/C	C	C	C	C
IE/F3	=	F3	F3	F3
IE/F1	=	F1	=	F1
IE/FE	FE	FE	FE	FE
IE/A3	IE	=	A3	=
IE/A1	IE	A1	IE	IE
IE/AE	=	AE	AE	AE
IE/C	C	IE	C	C
F3/F1	=	=	F3	F1
F3/FE	FE	FE	FE	FE
F3/A3	F3	F3	F3	F3
F3/A1	=	F3	F3	F3
F3/AE	=	=	=	=
F3/C	F3	C	=	C
F1/FE	=	=	FE	FE
F1/A3	F1	F1	F1	F1
F1/A1	F1	F1	F1	F1
F1/AE	F1	F1	F1	=
F1/C	C	=	=	C
FE/A3	FE	FE	FE	FE
FE/A1	=	FE	FE	FE
FE/AE	FE	=	FE	FE
FE/C	=	=	=	C
A3/A1	A1	=	=	A1
A3/AE	AE	AE	AE	AE
A3/C	C	C	C	C
A1/AE	A1	AE	AE	AE
A1/C	C	C	C	C
AE/C	=	AE	C	=

(dark pink)	A' more flexible (unanimous)	(light pink)	A' more flexible (3/4)
(dark blue)	B' more flexible (unanimous)	(light blue)	B' more flexible (3/4)
(green)	Equal flexibility (unanimous)	(light green)	Equal flexibility (3/4)
(orange)	50/50 split between 'equal' and one other option		
(light orange)	Variable mix of options	(violet)	50/50 between 'A' and 'B'

Judge 2

	Session			
A/B	1	2	3	4
I3/I1	I1	I1	I1	I1
I3/IE	IE	IE	IE	IE
I3/F3	F3	F3	F3	F3
I3/F1	F1	F1	F1	F1
I3/FE	FE	FE	FE	FE
I3/A3	A3	A3	A3	A3
I3/A1	A1	A1	A1	A1
I3/AE	AE	AE	AE	AE
I3/C	C	C	C	C
I1/IE	IE	=	IE	IE
I1/F3	F3	F3	F3	I1
I1/F1	F1	F1	F1	F1
I1/FE	FE	FE	FE	FE
I1/A3	I1	I1	I1	I1
I1/A1	I1	=	I1	A1
I1/AE	AE	AE	AE	AE
I1/C	C	C	C	C
IE/F3	F3	F3	=	F3
IE/F1	F1	F1	F1	F1
IE/FE	FE	FE	FE	FE
IE/A3	IE	=	IE	IE
IE/A1	IE	=	IE	IE
IE/AE	=	AE	IE	AE
IE/C	C	C	=	C
F3/F1	=	=	F1	F3
F3/FE	=	F3	=	=
F3/A3	F3	F3	F3	F3
F3/A1	A1	F3	F3	F3
F3/AE	F3	F3	=	=
F3/C	=	C	=	=
F1/FE	F1	=	F1	F1
F1/A3	A3	F1	F1	F1
F1/A1	F1	F1	F1	F1
F1/AE	F1	F1	F1	F1
F1/C	=	=	=	C
FE/A3	FE	FE	FE	FE
FE/A1	FE	FE	FE	FE
FE/AE	FE	=	FE	FE
FE/C	=	C	=	C
A3/A1	=	A1	A1	A1
A3/AE	AE	AE	AE	AE
A3/C	C	C	C	C
A1/AE	AE	=	AE	AE
A1/C	C	C	C	C
AE/C	C	AE	C	C

(dark pink)	A more flexible (unanimous)	(light pink)	A more flexible (3/4)
(dark blue)	B more flexible (unanimous)	(light blue)	B more flexible (3/4)
(green)	Equal flexibility (unanimous)	(light green)	Equal flexibility (3/4)
(orange)	50/50 split between 'equal' and one other option		
(peach)	Variable mix of options	(lilac)	50/50 between 'A' and 'B'

Judge 3

	Session				
A/B	1	2	3	4	
I3/I1	I1	I1	I1	I1	
I3/IE	IE	IE	IE	IE	
I3/F3	F3	F3	F3	F3	
I3/F1	F1	F1	F1	F1	
I3/FE	FE	FE	FE	FE	
I3/A3	A3	A3	A3	A3	
I3/A1	A1	A1	A1	A1	
I3/AE	AE	AE	AE	AE	
I3/C	C	C	C	C	
I1/IE	IE	I1	IE	=	
I1/F3	F3	F3	F3	F3	
I1/F1	F1	F1	F1	F1	
I1/FE	FE	FE	FE	FE	
I1/A3	=	I1	A3	=	
I1/A1	=	I1	=	A1	
I1/AE	AE	AE	AE	AE	
I1/C	C	C	I1	C	
IE/F3	=	F3	=	F3	
IE/F1	F1	F1	F1	F1	
IE/FE	FE	FE	FE	FE	
IE/A3	IE	IE	IE	IE	
IE/A1	IE	=	IE	=	
IE/AE	AE	AE	=	AE	
IE/C	C	C	C	C	
F3/F1	F1	=	=	F1	
F3/FE	=	FE	FE	=	
F3/A3	F3	F3	F3	F3	
F3/A1	F3	F3	F3	F3	
F3/AE	F3	=	F3	=	
F3/C	=	C	C	C	
F1/FE	=	=	FE	=	
F1/A3	F1	=	F1	F1	
F1/A1	F1	F1	F1	F1	
F1/AE	F1	F1	=	=	
F1/C	=	C	C	C	
FE/A3	FE	FE	FE	FE	
FE/A1	FE	FE	FE	FE	
FE/AE	=	=	AE	FE	
FE/C	=	=	=	=	
A3/A1	A1	=	=	=	
A3/AE	AE	AE	AE	AE	
A3/C	C	C	C	C	
A1/AE	AE	AE	AE	AE	
A1/C	C	=	C	C	
AE/C	C	C	=	C	

	A more flexible (unanimous)		A more flexible (3/4)
	B more flexible (unanimous)		B more flexible (3/4)
	Equal flexibility (unanimous)		Equal flexibility (3/4)
	50/50 split between 'equal' and one other option		
	Variable mix of options		50/50 between 'A' and 'B'

Judge 4

A/B	Session 1	2	3	4
I3/I1	I1	I1	I1	I1
I3/IE	IE	IE	IE	IE
I3/F3	F3	F3	F3	F3
I3/F1	I3	F1	F1	F1
I3/FE	FE	FE	FE	FE
I3/A3	A3	A3	A3	A3
I3/A1	A1	A1	A1	A1
I3/AE	AE	AE	AE	AE
I3/C	C	C	C	C
I1/IE	I1	IE	IE	IE
I1/F3	=	F3	F3	F3
I1/F1	F1	F1	F1	F1
I1/FE	FE	FE	FE	FE
I1/A3	I1	A3	A3	I1
I1/A1	=	A1	A1	=
I1/AE	AE	AE	I1	AE
I1/C	C	C	C	C
IE/F3	=	=	F3	F3
IE/F1	F1	F1	F1	F1
IE/FE	FE	FE	FE	FE
IE/A3	IE	IE	=	IE
IE/A1	IE	IE	IE	IE
IE/AE	AE	=	=	AE
IE/C	C	C	C	C
F3/F1	F1	=	F1	F1
F3/FE	FE	FE	F3	FE
F3/A3	F3	F3	F3	F3
F3/A1	F3	F3	F3	F3
F3/AE	AE	F3	=	AE
F3/C	C	C	=	C
F1/FE	=	FE	FE	FE
F1/A3	F1	F1	F1	F1
F1/A1	F1	F1	F1	F1
F1/AE	F1	AE	F1	AE
F1/C	=	C	=	C
FE/A3	FE	FE	FE	FE
FE/A1	FE	FE	FE	FE
FE/AE	FE	FE	FE	FE
FE/C	C	C	C	C
A3/A1	=	=	A3	A1
A3/AE	AE	AE	AE	AE
A3/C	C	C	C	C
A1/AE	AE	AE	AE	=
A1/C	C	C	C	C
AE/C	C	=	C	C

(deep pink)	A more flexible (unanimous)	(light pink)	A more flexible (3/4)
(blue)	B more flexible (unanimous)	(light blue)	B more flexible (3/4)
(green)	Equal flexibility (unanimous)	(grey-green)	Equal flexibility (3/4)
(orange)	50/50 split between 'equal' and one other option		
(peach)	Variable mix of options	(lilac)	50/50 between 'A' and 'B'

Judge 5

	Session				
A/B	1	2	3	4	
I3/I1	I1	I1	I1	I1	
I3/IE	IE	IE	IE	IE	
I3/F3	F3	F3	I3?	F3	
I3/F1	F1	F1	F1	F1	
I3/FE	FE	FE	FE	FE	
I3/A3	A3	=	A3	=	
I3/A1	A1	=	A1	A1	
I3/AE	AE	AE	AE	AE	
I3/C	C	C	C	C	
I1/IE	IE	IE	IE	=	
I1/F3	F3	F3	F3	F3	
I1/F1	F1	F1	F1	F1	
I1/FE	FE	FE	FE	FE	
I1/A3	=	I1	=	=	
I1/A1	A1	A1	=	=	
I1/AE	AE	I1	AE	AE	
I1/C	C	C	C	C	
IE/F3	=	IE	=	F3	
IE/F1	F1	F1	F1	F1	
IE/FE	FE	IE	FE	FE	
IE/A3	IE	IE	IE	IE	
IE/A1	IE	=	IE	IE	
IE/AE	AE	AE	AE	AE	
IE/C	C	C	IE	C	
F3/F1	=	=	=	F3	
F3/FE	FE	FE	FE	=	
F3/A3	F3	F3	F3	F3	
F3/A1	F3	F3	F3	F3	
F3/AE	=	F3	AE	=	
F3/C	C	C	C	=	
F1/FE	FE	=	=	F1	
F1/A3	F1	F1	F1	F1	
F1/A1	F1	F1	F1	F1	
F1/AE	=	F1	=	F1	
F1/C	=	=	C	C	
FE/A3	FE	FE	FE	FE	
FE/A1	FE	FE	FE	FE	
FE/AE	AE	=	=	FE	
FE/C	C	=	=	=	
A3/A1	=	A1	A1	A1	
A3/AE	A3	AE	AE	AE	
A3/C	A3	C	C	C	
A1/AE	AE	AE	AE	AE	
A1/C	C	C	C	C	
AE/C	C	=	C	C	

(pink)	A more flexible (unanimous)	(light pink)	A more flexible (3/4)
(blue)	B more flexible (unanimous)	(light blue)	B more flexible (3/4)
(green)	Equal flexibility (unanimous)	(light green)	Equal flexibility (3/4)
(orange)	50/50 split between 'equal' and one other option		
(peach)	Variable mix of options	(lilac)	50/50 between 'A' and 'B'

Judge 6

	Session			
A/B	1	2	3	4
I3/I1	=	I1	I1	I1
I3/IE	IE	IE	IE	IE
I3/F3	F3	F3	F3	F3
I3/F1	F1	F1	F1	F1
I3/FE	FE	FE	FE	FE
I3/A3	=	A3	=	A3
I3/A1	A1	A1	A1	A1
I3/AE	AE	AE	AE	AE
I3/C	C	C	C	C
I1/IE	IE	IE	IE	IE
I1/F3	F3	F3	F3	F3
I1/F1	F1	F1	F1	F1
I1/FE	FE	FE	FE	FE
I1/A3	=	=	=	=
I1/A1	A1	A1	A1	A1
I1/AE	AE	=	AE	AE
I1/C	C	C	C	C
IE/F3	=	IE	=	F3
IE/F1	=	F1	=	F1
IE/FE	IE	FE	=	FE
IE/A3	IE	IE	IE	IE
IE/A1	=	=	IE	IE
IE/AE	AE	AE	=	=
IE/C	=	C	C	C
F3/F1	F1	F1	=	=
F3/FE	=	FE	=	=
F3/A3	F3	F3	F3	F3
F3/A1	F3	F3	=	=
F3/AE	AE	=	=	=
F3/C	C	C	=	=
F1/FE	=	=	FE	=
F1/A3	F1	F1	F1	F1
F1/A1	F1	F1	F1	F1
F1/AE	=	F1	F1	=
F1/C	C	=	=	=
FE/A3	FE	FE	FE	FE
FE/A1	FE	FE	FE	FE
FE/AE	=	=	=	FE
FE/C	=	=	=	=
A3/A1	=	A1	A1	=
A3/AE	AE	AE	=	AE
A3/C	C	C	C	C
A1/AE	A1	AE	AE	=
A1/C	=	C	C	C
AE/C	C	=	C	C

	A more flexible (unanimous)		A more flexible (3/4)
	B more flexible (unanimous)		B more flexible (3/4)
	Equal flexibility (unanimous)		Equal flexibility (3/4)
	50/50 split between 'equal' and one other option		
	Variable mix of options		50/50 between 'A' and 'B'

Judge 7 (results not used in analysis)

	Session				
A/B	1	2	3		
I3/I1	=	I1	I1		
I3/IE	IE	IE	IE		
I3/F3	F3	F3	F3		
I3/F1	F1	F1	F1		
I3/FE	FE	FE	FE		
I3/A3	A3	=	A3		
I3/A1	=	A1	A1		
I3/AE	AE	AE	AE		
I3/C	C	C	C		
I1/IE	IE	IE	IE		
I1/F3	F3	F3	F3		
I1/F1	F1	F1	F1		
I1/FE	FE	FE	FE		
I1/A3	I1	=	=		
I1/A1	A1	A1	=		
I1/AE	AE	AE	=		
I1/C	C	C	C		
IE/F3	F3	=	=		
IE/F1	F1	=	=		
IE/FE	=	FE	FE		
IE/A3	IE	IE	IE		
IE/A1	IE	IE	=		
IE/AE	=	IE	=		
IE/C	C	=	C		
F3/F1	=	=	F1		
F3/FE	=	FE	FE		
F3/A3	F3	F3	F3		
F3/A1	F3	F3	F3		
F3/AE	F3	=	=		
F3/C	=	=	C		
F1/FE	=	=	=		
F1/A3	F1	F1	F1		
F1/A1	F1	F1	F1		
F1/AE	F1	F1	F1		
F1/C	F1	F1	=		
FE/A3	FE	FE	=		
FE/A1	FE	FE	FE		
FE/AE	FE	FE	FE		
FE/C	=	C	C		
A3/A1	A1	A1	A3		
A3/AE	AE	AE	AE		
A3/C	C	C	C		
A1/AE	=	=	AE		
A1/C	C	C	C		
AE/C	C	C	C		
	A more flexible (unanimous)			A more flexible (2/3)	
	B more flexible (unanimous)			B more flexible (2/3)	
	Equal flexibility (unanimous)			Equal flexibility (2/3)	
	Variable mix of options				

Appendix VIII Kendall's coefficient of agreement (u)

Kendall's coefficient of agreement is calculated by:

$$u = \frac{2\sum}{\binom{m}{2}\binom{n}{2}} - 1$$

Where m = the number of judges

$$\binom{m}{2} = \tfrac{1}{2}.m(m-1)$$

n = the number of specimens

$$\binom{n}{2} = \tfrac{1}{2}n(n-1)$$

$\sum$ = The sum of ½.y(y – 1) for each specimen

y = The number of judges preferring a specimen over another (e.g., scores in Table 5.7)

Working for section 5.5.2:

Six judges were compared, each having assessed 10 specimens

$$\binom{m}{2} = 15 \qquad \binom{n}{2} = 45$$

$\sum$ = 545.1 (for values in Table 5.7)

u = [(2 x 545.1) / (15 x 45)] – 1

u = 0.62

Test for significance

The significance test is derived from the chi-squared distribution.

The chi-squared value is calculated by:

$$\chi^2 = \frac{4}{m-2}\left\{\sum - \frac{1}{2}\binom{m}{2}\binom{n}{2}\frac{m-3}{m-2}\right\}$$

Where m, n and ∑ are the same as above, arriving at a value of 292 for the above example.

The degrees of freedom are $\nu = \binom{n}{2}\frac{m(m-1)}{(m-2)^2}$,

giving 84.4 for the above example.

The deviate, or z-value that can be used to find significance in normal distribution tables, is calculated by:

$\sqrt{2\chi^2} - \sqrt{(2\nu - 1)}$,

giving a deviate of 11.21 for the above example.

The deviate is so large that the probability of obtaining the observed coefficient of agreement is $p<0.001$, making it unlikely the observed agreement among judges was due to chance.

Appendix IX Mud-silk specimens