Gelatin and Carrageenan Mixtures: Use of Proteinaceous and Carbohydrate Adhesive Combinations for Consolidating Southeast Asian Paintings

Summary

In 2009, the consolidation treatment of 33 very large Southeast Asian paintings on fabric provided an opportunity to evaluate the working characteristics of two adhesives: gelatin and carrageenan. These two adhesives were evaluated in mixtures of different proportions to achieve the desired levels of viscosity, penetration, strength, flexibility, and visual appearance. Varying proportions, concentrations, and application methods were found useful for different treatment situations.

Section 1. Introduction

The Asian Art Museum (AAM) received 167 Southeast Asian paintings, objects, and textiles in 2002 from the Doris Duke Charitable Foundation. Duke (1912-1993) had kept these works in an indoor tennis court building in Hillsborough, New Jersey (figure 1). In 1999, after Duke's death but before her estate was dispersed, Hurricane Floyd caused record storm surges along the New Jersey coast, flooding Duke Farms. The artworks were severely damaged, sustaining mud tidelines, flaking, warping, rust, and mold.

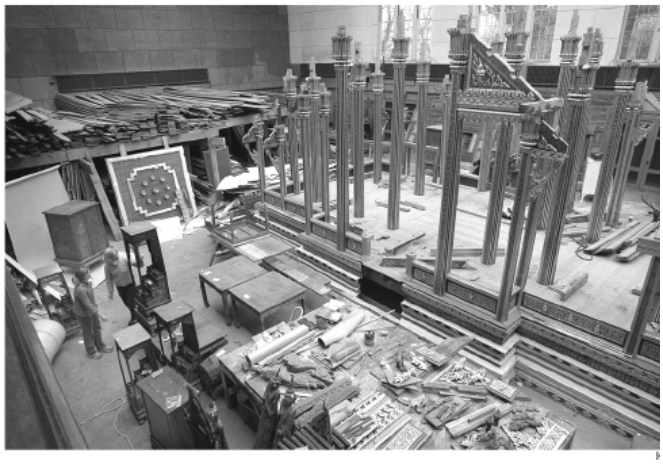

Figure 1. Indoor tennis court, Duke Farms, Hillsborough, New Jersey, 2002. Image courtesy of the Asian Art Museum of San Francisco

In preparation for AAM's special exhibition, *Emerald Cities: Arts of Siam and Burma*, which was on display from October 23, 2009 through January 10, 2010, the AAM Conservation Center conserved a total of 145 artworks from the AAM's Southeast Asian collection. Seventy percent of the artworks for the exhibition were from the Doris Duke Charitable Foundation's donation.

Many of the paintings were found to be highly unstable, due to their construction method and to poor storage. The paintings were stored in the Duke Farm's tennis court stacked up and/or rolled. This storage method is actually thought to be similar to what the paintings would have experienced if they had remained in their original environment. It is believed that these paintings were made as offerings for Buddhist ceremonies and were not meant for a long-term use, so good storage was not a priority. For the same reason the production of the paintings was also technically rather poor (unlike the quality of thangka paintings, which are generally, and mistakenly, thought of as similar in construction). Thus in order to physically stabilize the paintings, consolidation of the painting media was a critical step in the conservation treatment.

Among those artworks for the *Emerald Cities* exhibit, 33 paintings on fabric supports were treated to stabilize them for safe display. The smaller paintings are approximately 3 feet high and 2 feet wide, and nine large ones are as much as 11feet high and 4 feet wide. The painting laboratory had a little over one year to prepare them for the exhibition. With these serious time constraints, physical stabilization was the priority. Suitable consolidants needed to be determined to stabilize the severely flaking paint media.

Section 2. Methodology

As the first step of the conservation treatment, testing was carried out to determine the best consolidant. Three characteristics were required:

- The consolidant must have very good penetration into both the pigment and ground layers by traveling slowly on a suction table.
- It must maintain flexibility.
- It must maintain a matte appearance.

The amount of consolidant needed for the large number of over-sized paintings would be quite large, creating another necessary requirement:

- Preparation of the consolidant must be straightforward and produce consistent quality.

Pure isinglass was initially considered, prepared from sturgeon air bladder membrane. But the resultant isinglass film was found to be too varied; some samples were flexible and others brittle. A consolidant film made from a mixture of isinglass and *funori* has occasionally been used at AAM in the past. This film was very flexible and difficult to break by folding repeatedly. I thought this film had great potential as a consolidant for this application.

Two seaweed-based adhesives (natural carbohydrate polymers) were also considered. The unique character of *funori* has been reported in conservation articles such as Swider and Smith 2005.[1] *Funori* has been long used in Japanese painting conservation, and many paper conservators are familiar with its application. Carrageenan was the second seaweed adhesive tested for this project. Carrageenan is manufactured from red edible seaweed, processed as a refined powder of a light cream color. It has been used in food and other industries as a thickening and/or stabilizing agent.

Using AAM's isinglass-*funori* consolidant film as a starting point, I compared the selected materials to determine the candidate that best met our criteria. Six consolidant mixtures were prepared, using four ingredients:

- Isinglass 5% v/w in deionized water.
- Gelatin, photographic grade 5 % w/v in deionized water.
- *Funori*, a 2”x3” sheet, slowly cooked in a double pan with 100ml de-ionized water, and gently sieved with two layers of fine gauge cotton.
- Carrageenan 1 % w/v in deionized water.

The components were prepared individually in glass beakers, and continually warmed (approximately 60 to 70 degrees Celsius) and stirred until completely dissolved. Solutions were then mixed in two different ratios: 1:1 protein:seaweed and 3:1 protein:seaweed. Isinglass was tested with *funori*; gelatin was tested with both *funori* and carrageenan.

Results

The results of the initial testing are summarized in the chart below.

Film appearance

Cast films were evaluated for color and clarity. Each mixture was stirred and poured onto a silicon release polyester sheet to dry. During the drying, it was noted that *funori* and isinglass solutions created lines, as if the two ingredients separated on the polyester sheet. Dried consolidant sheets showed slight differences. The gelatin-carrageenan mixtures were very clear, and much less yellow than other two types of *funori* mixtures. The dried films prepared with more carrageenan were much more flexible.

Adhesive penetration

Next, the mixtures were tested on paper to evaluate penetration and gloss. Each mixture was tested on three different prints: a black and white etching on a light-weight cotton paper from a late 19th or early 20th-century book; a fragment of a contemporary color etching on heavy-weight cotton paper (figure 2); and a fragment of a color lithograph on a heavy-weight paper. A 1% w/v solution prepared from each dried film with de-ionized water was applied to the prints using fine brushes on a suction table. The prints were left on the suction table until dried and the results were examined under normal and UV light.

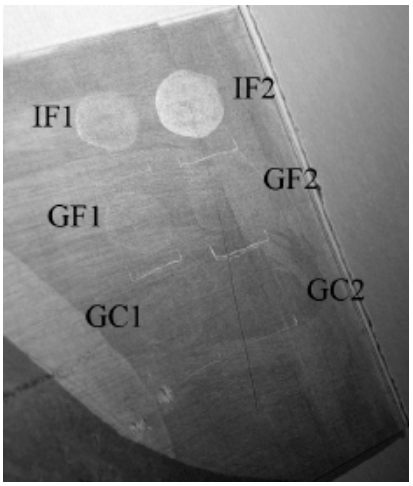

Figure 2. Consolidants tested on a fragment of contemporary color etching on heavy-weight cotton paper.

Clockwise from upper left:

IF1 and IF2 (most shiny)

GF2 and GC2 (most matte)

GC1 and GF1.

Photographed at the time of consolidant testing.

The mixtures of isinglass and *funori* were visible on the surfaces of all prints. They appeared to have remained on the surface, failing to penetrate well to the versos of the prints. The mixtures of gelatin and *funori* acted similarly, and penetration to the versos of the prints was uneven. The mixtures of gelatin and carrageenan resulted in print surfaces with the least gloss among the tested solutions. The surface of the prints remained matte, and the adhesive penetrated well into the versos of the prints.

	MIXTURE RATIOS				TEST RESULTS				
Consolidant	**Isinglass** 5% w/v	**Gelatin** 5% w/v	**Funori** 2"x 3" in 100 ml water	**Carrageenan** 1% w/v	**Appearance**	**Penetration**	**Gloss**	**Flexibility**	**After aging 18 months**
IF1	1		1		lines, yellow	low	glossy	OK	Darkened
IF2	3		1		lines, yellow	low	glossy	OK	Darkened
GF1		1	1		yellow	uneven	glossy	OK	Less, but darkened
GF2		3	1		yellow	uneven	matte	OK	Less, but darkened
GC1		1		1	clear	good	OK	best	OK, some tidelines on recto
GC2		3		1	clear	good	matte	best	Best Less darkening, some tidelines on recto

Aging

The tested prints were re-examined 18 months after the date of the testing. The tested areas of the prints showed different degrees of discoloration. Because the application of the consolidant mixtures was carried out on a suction table followed by drying on the table, no discoloration or tidelines were noted on the prints at the time of testing.

Upon re-examination, it was noted that the mixtures of isinglass and *funori* made the darkest discoloration, and IF2 (lower ratio of *funori* in the mixture) had slightly darker discoloration. The mixtures of gelatin and carrageenan showed the least discoloration among all consolidants. GC2 (more carrageenan in the mixture) had the least discoloration. However tidelines did form on the rectos of tested prints, so this remains a concern. For this particular treatment, however, the consolidant was applied overall on the painting surfaces so the risk of local tidelines was low.

Discussion

The best consolidants were the mixtures of gelatin and carrageenan, which produced very clear dried consolidant films. These films were very flexible, and could not easily be broken by folding repeatedly by hand. It is expected to maintain the same flexibility on the paintings. Coincidentally, the gelatin-carrageenan mixture was the simplest to prepare, because the ingredients did not require separate preparation. This would help ensure consistent quality.

The ratio of carrageenan also affects the matte appearance on the tested prints. Although it was assumed that a higher proportion of gelatin would make the consolidant mixtures shinier, GF2 and GC2 resulted in the most matte appearance.

One question remained. Would the consolidant with more gelatin form crystals along the fragmented pigment particles when applied in a higher concentration? This was not tested on the prints, but it was expected that some crystallization of gelatin on the pigment surface would occur. This left the final candidate GC1: gelatin and carrageenan in a 1:1 mixture.

NOTE see facing page

~~**Section 3. Gelatin-Carrageenan Mixtures for Consolidation of Paintings**~~

~~Following the testing, gelatin-carrageenan mixtures were used on a number of paintings from the Duke Collection, using different mixture ratios for different treatment needs. Three paintings are described here as examples: a painting executed on fabric with thick ground layer; a painting on fabric with no ground layer; and a painting on wood. Different ratios of gelatin to carrageenan and different application methods were used for each treatment. The gelatin-carrageenan consolidant mixtures used in the treatments can be summarized in the examples that follow.~~

Painting example 1: Fabric with thick ground layer

Scenes from the Life of the Buddha
Thailand, approximately 1800-1850
Pigments and gold on cloth, 99 7/8" H x 45 1/8" W
Gift from Doris Duke Charitable Foundation's Southeast Asian Art Collection, Asian Art Museum of San Francisco

This painting was executed on medium-weight, coarsely woven cotton fabric with a very friable, fairly thick ground layer (figure 3). Thread count of the painting is 17 and 16 per square centimeter. The ground layer was applied from the recto of the primary fabric support in order to make the surface smooth enough to be painted. Pigments and gold paint were then applied with narrow blank areas on the edges. This painting is unlined, and the primary support was very soft and flexed easily.

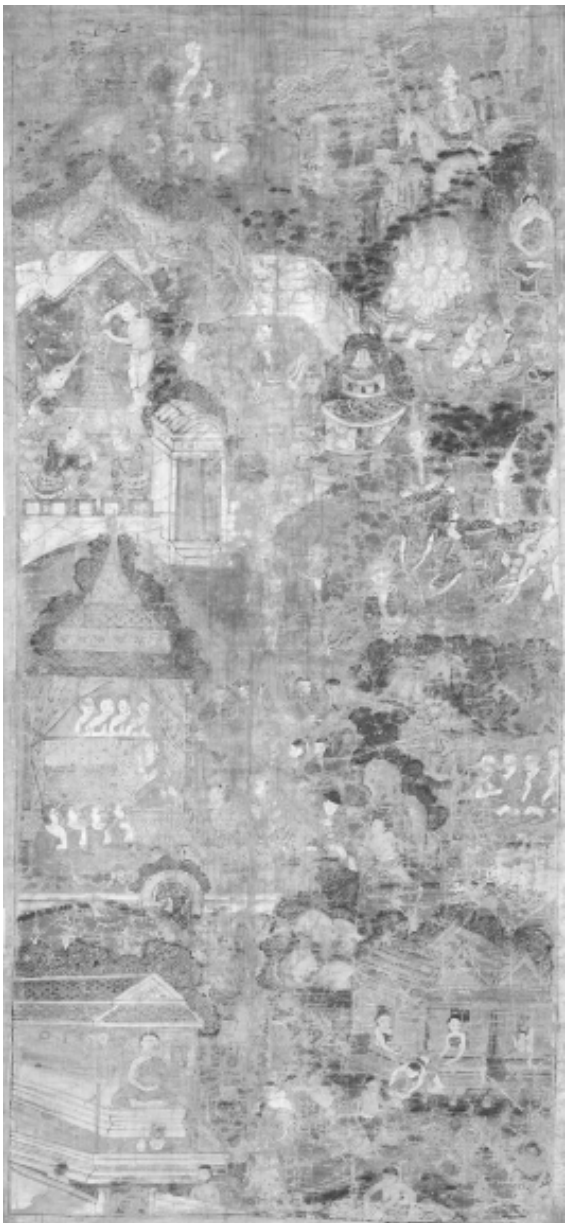

Figure 3. *Scenes from the Life of the Buddha*

This is the correct text and the chart that was inadvetantly left out of the original article.

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Consolidant	**Gelatin** 5% w/v	**Carrageenan** 1% w/v	**Ratio gelatin: carrageenan**	**Viscosity**
G1	3.0g in 60ml	0.6g in 60ml	1:1	highest
G2	3.0g in 60ml	0.3g in 30ml	2:1	medium
G3	3.0g in 60ml	0.2g in 20ml	3:1	lowest

The pigment and ground layers on this painting were flaking severely. However, it was noted that areas with coarsely ground mineral pigments remained better adhered to the primary support than did the thinly applied areas of organic pigments. Probably the larger amount of binder required by the coarse pigments contributed to securing the ground layer.

The pigment surface was so friable that the fragments lifted when touched with wet brushes. Therefore, a 0.5 % w/v G1 solution was first delivered as a mist using an ultrasonic humidifier on a suction table in order to secure the finest, most powdery pigments. Tweezers were used to realign the pigment fragments in their correct positions. The second step was to apply a stronger, 1% G1 consolidant to secure small fragments using medium sized brushes on the suction table. The condition was improved, but the painting needed to be further consolidated so this application was repeated three times. A stronger 1.5% G1 consolidant was then applied with larger brushes on the suction table.

The condition of the flaking and consolidants was again reevaluated. The pigment layer appeared secure, but the ground layer still needed a stronger consolidant. Another consolidant (G2) was then made with more gelatin and less carrageenan. The fourth step was to use this consolidant in a higher concentration of 1.75% in order to further secure large fragments. After one application of this consolidant, the pigment and ground layers were finally considered stable.

At this point, a crystalline shine was noted along the edges of the fragmented pigments under the laboratory working light. Although it is not visible under normal lower lighting, it seems that 1.75% is the highest concentration that can be applied if the G2 solution is used. It may be that a repeated application of weaker consolidant would work without risking crystal formation. However, a single application of a stronger consolidant secured the pigment and ground layers better, so this was used.

During the application steps, it was noted that the ground layer softened when wet, even after consolidants were repeatedly applied. It came to resemble cookie dough, difficult to touch or apply pressure to. By placing blotter paper on the painting surface and applying suction pressure, better contact was achieved between the pigments and the fabric support than by using small weights on top.

Painting example 2: Fabric with no ground layer

Standing Buddha Flanked by Two Disciples; and Five Scenes of the Buddha's Previous Lives
Thailand, approximately 1850-1900
Pigments and gold on cloth, 115 3/4" H x 36 1/2" W
Gift from Doris Duke Charitable Foundation's Southeast Asian Art Collection, Asian Art Museum of San Francisco

The second example is a painting executed on light-weight, tightly woven fabric with no ground layer (figure 4). Thread count of the painting is 32 and 34 per square centimeter. Pigments and a gold paint were applied directly to the primary fabric support, and the painting is unlined. The pigment layer has a uniform, shiny surface, and is still fairly intact, possibly due to the use of a larger amount of binder, or to a previous consolidation. However, a moderate level of flaking was still noted, particularly along the losses, creases, and folds. These areas required consolidation. Severe damage is in the form of darkened pigment and badly degraded primary support associated with a green pigment.[2]

Consolidant, prepared as a 1% solution of G1, was delivered in a single application using medium size brushes on the suction table. After completion of the consolidation, the pigment layer was secured.

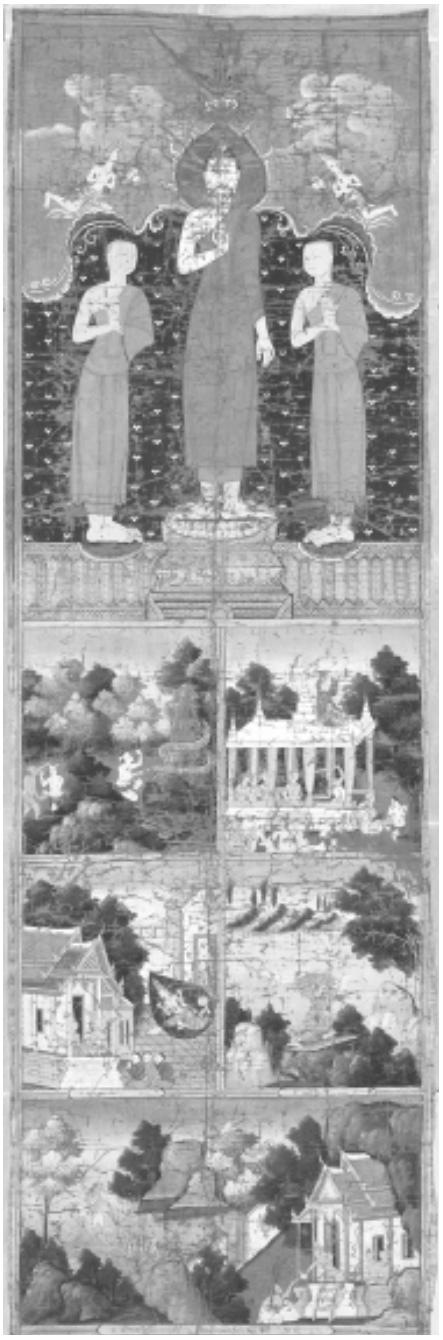

Figure 4. *Standing Buddha Flanked by Two Disciples; and Five Scenes of the Buddha's Previous Lives.*

Figure 5. *The Great Departure of the Buddha-to-Be from His Father's Palace, and the Cutting of the Hair*

Painting example 3: Wood substrate

The Great Departure of the Buddha-to-Be from His Father's Palace and the Cutting of the Hair
Thailand, approximately 1850-1900
Pigments and gold on wood
24 1/2" H x 16 1/2" W
Gift from Doris Duke Charitable Foundation's Southeast Asian Art Collection, Asian Art Museum of San Francisco

The final example is a painting executed on a single flat board of dark hardwood (figure 5). The face of the board has a thin, off-white ground, and the design is painted in matte colors and gold. Microscopic examination of the stratigraphy shows that there is red underpaint under the black lines and that the blue sky was painted in entirely before the figures occupying that part of the composition were painted on top. The paint and ground layers were heavily cracked with much lifting and loss overall, especially in the upper half.

Consolidation was carried out with a 1% solution of G1 consolidant. Because of the severely lifted pigmented surface, a piece of very thin Japanese paper or rayon tissue was first laid over a section and wet with a 1:2 ethanol/water mixture to dampen the paper and the underlying pigment surface. This was immediately followed by the application of the consolidant with a smaller brush, generally diluted further by dipping the brush first in warm water. After allowing several minutes for penetration the paper was gently lifted off and discarded. Additional consolidant was then applied with a fine brush to the edges of losses, cracks and other areas where it would penetrate under the pigments. By wetting large, adjacent areas consecutively, each before the previous one was dry, tidelines and water marks were prevented. The pigments were successfully secured.

Section 4. Conclusions

In conclusion, the conservation treatment of this series of Southeast Asian paintings was successfully carried out using gelatin-carrageenan mixtures.

At AAM, the Southeast Asian paintings on fabric supports are rolled onto large archival tubes for storage due to their very large size and museum storage limitations. Many Asian paintings are traditionally rolled for storage, including most East Asian hanging scrolls, and the rolling and unrolling is often a major cause of flaking pigments. These Southeast Asian paintings are no exception, and are frequently unrolled for scholarly research, exhibition, and loan. However, since the completion of these treatments, we have found that the treated paintings have remained stable, with very little local flaking.

In the years following this initial research, the G-series gelatin-carrageenan mixtures have been successfully used on a range of different Asian paintings. The mixtures have been used on Himalayan and Chinese thangkas to secure large fragmented pigments through direct application. And on East Asian scrolls and South Asian paintings, they have been applied as a mist for pigmented areas that had become powdery.

It is important to realize that the different ratios and different application methods must be tailored to each individual project. For example, when the gelatin-carrageenan solutions are used in a mist, a lower ratio of carrageenan (G3) is less viscous and so a mist can be easily created using an ultrasonic humidifier.

A lower ratio of carrageenan (G2 or G3) is recommended when the consolidant needs to be applied in high concentration, because those G2 or G3 consolidants tend to be too runny in lower concentrations, travel through the pigments and ground layers too quickly, and require multiple applications to secure larger pigments.

An obvious crystallization of the gelatin can occur when the G2 solution is made to 1.75% or higher concentration, although it is not visible under normal lower lighting levels. This was a dilemma because repeated applications of more diluted consolidant were not effective, while a single application of a stronger consolidant secured the pigment and ground layers better.

As with all conservation, risks are involved, and the adhesives are not suitable for every case. The gelatin-carrageenan mixtures can provide flexibility and versatility, and have proved to be a useful tool for consolidating thickly applied pigments on flexible fabric supports.

Materials:

Russian Sturgeon Bladders.
Conservation Support System, Santa Barbara, CA.
Gelatin, Photographic grade. Talas, NY.
Funori. Hiromi Paper International, CA.
Carrageenan. Talas, NY.

Acknowledgments:

The author would like to thank Dr. Charlotte Eng at the Los Angeles County Museum of Art for her kind analysis of the pigments and Ms. Katherine Holbrow, former Head of Conservation at AAM, currently Director of Conservation at ARTEX for her support throughout the project and preparation of this article.

1. Swider, Joseph R and Smith, Martha. "Funori: Overview of a 300-Year-Old Consolidant," *JAIC*, 2005, Volume 44, Number 2, (pp. 117-126).

2. A green sample was analyzed by Dr. Charlotte Eng at the Los Angeles County Museum of Art using FTIR and XRF and was found to be copper acetoarsenite (emerald green), a pigment commercially manufactured in Germany in 1814. Emerald green is extremely toxic, can be decomposed by acids and warm alkalis, and darkens in the presence of sulfur. All of these reactions were certainly noted with this painting.