The Consolidation of Flaking Gouache on Japanese Paper

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SUMMARIES

The consolidation of flaking gouache on Japanese paper

Some gouache works, made in the 1930s by Claude Autant-Lara, were damaged in die paint layer. Extensive areas of gouache including areas of overlapping layers of paint were very cracked. Some of these were even flaking. In order to select the appropriate treatment, we compared the properties of five different strengthening agents, prepared to the same concentration (l°/o) or same viscosity (3 cp), resp. Samples of gouache, as close as possible to the work of art were prepared, submitted to accelerated ageing and then consolidated with the strengthening agents: gelatine, sturgeon glue, polyvinyl alcohol, methylhydroxyethylcellulose and Paraloid B72. Adhesive and cohesive strength were measured using a peeling test and a shearing test in a traction machine. The different kinds of break and their areas were studied in order to evaluate the particularities of each product and the best one for the case in question.

La consolidation de gouaches écaillées sur papier Japon

Des gouaches réalisées par Claude Autant-Lara au cours des années 1930 présentaient plusieurs types de dégradation. De grandes couches de gouache, quelquefois superposées les unes aux autres, étaient très craquelées et certaines même écaillées. Afin de trouver une méthode de traitement appropriée nous avons comparé les propriétés de cinq agents consolidant différents prépares respectivement au même taux de concentration (1%) et de viscosité (3cp). Des échantillons de gouache se rapprochant le plus possible du cas étudie ont été prépares, soumis au vieillissement artificiel, puis consolides au moyen des agents suivants : gélatine, colle d'esturgeon, alcool polyvinylique, méthylcellulose et Paraloid B72. Les forces d'adhésion et de cohésion ont été étudiées a 1'aide d'un test de pelage et d'un test de cisaillement par un appareil de mesure de résistance a la traction. Ensuite la nature des ruptures et les différents endroits ou elles se sont produites ont été étudies afin d'évaluer les particularités de chaque agent consolidant et de sélectionner celui qui est le mieux approprie au cas étudie.

Die Festigung van abblatternder Gouache aufjapanpapier

Einige Gouache-Blatter aus den 30er Jahren des 20. Jh. von Claude Autant-Lara wiesen schwere Schaden auf. Weite Bereiche, deren Farbschichten teilweise ubereinander lagen, zeigten Craquele, einige schuppenformige Abhebungen. Um eine geeignete Behandlungsmethode zu finden, wur-den funf verschiedene Festigungsmittel getestet: Gelatine, Hausenblase, Polyvinylalkohol, Methyl-cellulose und Paraloid B72. Sie wurden in gleicher Konzentration (1%) bzw. in gleicher Viskosi-tat (3 cp) zubereitet. Sodann wurden Muster hergestellt, die in Material und Aufbau den zur Rede stehenden Kunstwerken moglichst nahe kamen, und mil den genannten Festigungsmitteln behandelt. Mit Hilfe eines Zugfestigkeitspriifgerats wurden in einem Abschal-, und in einem Schertest Adhasion und Kohasion gemessen. Danach wurden Art und Bereich der auftrtetenden Briiche untersucht, um die spezifische Wirkung der Festigungsmittel zu erfassen.

INTRODUCTION

We had to consolidate five gouache studies for scenery, made by Claude Autant-Lara around 1937. All were very cracked, although only one painting was flaking. The gouache used was made out of gum arabic, according to a traditional recipe. The gouache was thick and layered in places. It was painted on a Japanese paper called "Imperial japon", made out of eastern mitsumata fibers. The spatial density of the cracks was variable, depending on the paint colour, its thickness, and whether it had been applied onto another layer. We noticed that the red colour and its variants, purple and orange, were always cracked. On the other hand, the white and mixtures containing it, never cracked. It appeared that cracking was most evident in the areas where gouache had been applied thickly and particularly where there were multiple layers of paint. Flaking was due to both a loss of cohesion within the colour (cracks), and a loss of adhesion between the paint layer and the paper support (flakes).

The formation of the cracks was caused by several factors. Gouache is water-based consisting of a pigment, a mineral charge (calcium carbonate), a binding agent (traditionally gum arable) and water, primarily the solvent for the binding agent and partly remaining in the paint layer as a plasticizer. The water particles are bound to the hydrophilic gum arabic particles, allowing them to slide and make the paint layer flexible. However, water evaporates; which is why water-retaining substances such as honey or, more recently, glycerol[1], were added to gouache. In the case reported here, the paint seems to have been quite thick, which gives intensity to the colour, but also means there is a tendency for the paint to become brittle. Moreover, the thicker the paint layer, the stronger the internal tensions during drying. While a thin layer of gouache dries quickly and evenly, the top area of a thick layer dries more quickly than the material beneath. Very often, the tensions between layers result in concave[2] concentrating humidity. The surface tension and the forces within the paint layer work in the same direction, i.e. parallel, but not in equal amounts, which results in cupping[1]. Quite often cracks, which appear during ageing, are due to the loss in elasticity of the binding agent. Indeed, gum arabic loses water in the course of ageing. Hydrolysis and the photo-oxidation of its glucosidic molecules results in chain scission, which leads to the production of glucose units. Cupping can become deeper with time, lift from the support, and form flakes by absorbing and desorbing free water from the atmosphere. As soon as cracks appear, water is no longer distributed evenly through the entire paint layer, it flows more easily through cracks[4] causing variation in tension in the cracked areas.

Consolidation of flaking gouache can be achieved by regeneration of the binding agent or by adding a strengthening agent. The former can be achieved by humidifying in a water saturated atmosphere. However, this is not a real regeneration. Indeed, a fraction of the water contained in a non-altered paint layer is chemically bound to the gum arabic. Thus, desiccation associated with natural ageing is an irreversible chemical phenomenon. However, humidification can ease the application of a strengthening agent. It may indeed soften the cupped areas, so that they can be flattened with light pressure. The other alternative, the addition of a strengthening agent into the paint layer, can be seen as being problematic because it is practically irreversible.

Gouache consolidation aims at strengthening the cohesion of the paint layer and its adhesion to the paper support. Two qualities of the agent in liquid form are of crucial importance: surface tension and viscosity. Both influence the way it penetrates into the paint layer.

Comprehensive studies were necessary to select a good strengthening agent. Indeed, in consolidating the large painted areas we had to find something chemically and physically stable, as well as aesthetically neutral. Samples, or dummies of the paints in question were made, using materials as close as possible to those used by the artist. After artificial ageing, the samples were consolidated with several different concentrations of dissolved agents. After drying, a peeling and a shearing test were performed.

THE STRENGTHENING AGENTS

We tested three different types of agent:

- Two natural products: gelatine and sturgeon glue[1]. They are both traditionally used in the consolidation of flaking gouache.
- Two synthetic water-soluble polymers: a methylhydroxyethylcellulose (Tylose MH 300, Hoechst), and a polyvinyl alcohol (Rhodoviol 4/125, Hoechst). The first has a good adhesive power and a high viscosity even at low concentrations. The other is used as a modern binding agent for watercolour and in the paper industry for coating[6].
- A synthetic solvent soluble polymer: Paraloid B72 (Rohm & Haas), dissolved in 40% toluene and 60% ethanol. It is one of the most commonly used resins in conservation. However, secondary effects have been observed when applied to paper'.

Two solutions were prepared for each of these compounds. The first was a 1% solution, which is the maximum concentration used for aqueous strengthening agents. Indeed, if used at a higher concentration, the product would start to be noticeable and make the gouache brighter. Note that the viscosity of the 1% solutions varied with the different substances (Table 1).
The second solution was prepared so that its viscosity was 3 cP. This corresponded to the minimum concentration for the consolidation of flaking pigment on paper using poly vinyl alcohol and Paraloid B72. For the other, more viscous adhesives, the concentration resulting in 3 cP viscosity was different: 1% for gelatine and less than 0.5% for methylhydroxyethylcellulose (Table 2). For sturgeon glue, this viscosity could not be achieved: 1% concentration resulted in 1.5 cP viscosity, any higher was already in a gel.

Table 1: Viscosity (cP) of different concentrations.

Concentration (%)	Gelatine	Sturgeon glue	Polyvinyl alcohol	MHE cellulose	Paraloid B72
3			3.09		2.6
2,5			2.13		1.95
2			1.8		1.64
1.5			1.59		1.57
1	3.68	1.33	1.36	25.78	1.29
pH	*6.7*	*7.7*	*6.9*	*7.8*	
0.5	1.55	1.04	1.04	8.48	1.15

Table 2: Concentrations resulting in ca. 3 cP viscosity.

	Gelatine	Sturgeon glue	Polyvinyl alcohol	MHE cellulose	Paraloid B72
Concentration (%)	1	any > 1	3	less than 0,5	4.25
Viscosity (cP)	3.07	gel	2.9	3.21	3.09
pH	6.7		6.5	7.3	

THE TESTS

In the industry, adhesiveness is measured according to specific rules defined by the *Association Frangaise de Normalisation* (AFNOR). This standard method characterises adhesiveness by measuring the minimum force necessary to detach two materials, an adhesive strip and a piece of paper, for example. Unfortunately, this is not a good model for our handmade composite samples, which were made of three materials: adhesive strip, paint and paper. In particular, the force registered by the machine was not relevant, as it measured a combination of the strength of the gouache layer's cohesion and its adhesion to the paper. We therefore use another figure of merit: the peeled or the sheared surface area of the gouache layer after the test strengthening agent had been applied.
We developed two different tests, in order to characterise quantitatively the efficiency of each strengthening agent. The first was a peeling test aimed at measuring the adhesion of the gouache to the paper before and after consolidation.
The second test was an attempt to measure both the cohesion within the paint layer and its adhesion before and after consolidation. For this purpose, we applied a constant uniform force within the system defined by the gouache layer and studied how the gouache layer broke.

Description of the machine

For both tests, a tension testing machine, applying constant tensile loads was used. This machine consists of a fixed part, holding the sample, and a mobile part, which can move parallel to the sample.

Preparation of the samples

For both tests, a gouache made from gum arabic was applied to a Japanese paper called *torinoko.* (71 g/m^2). This paper was close to die Japanese paper used for the painting in question.
Two colours of gouache were chosen for their medium resistance to ageing: sky blue and red. The red was applied easily; the blue, however, was too thick and had to be diluted with 10% distilled water. For each test, three kinds of gouache samples were prepared and studied. The first and second samples were made with blue and red gouache respectively, while the third sample consisted of a layer of red on top of a layer of blue.

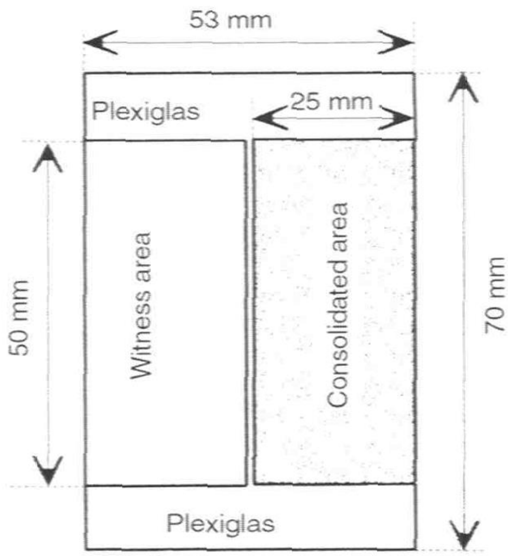

Fig. 1: *Scheme of the peeling test: preparation of the sample.*

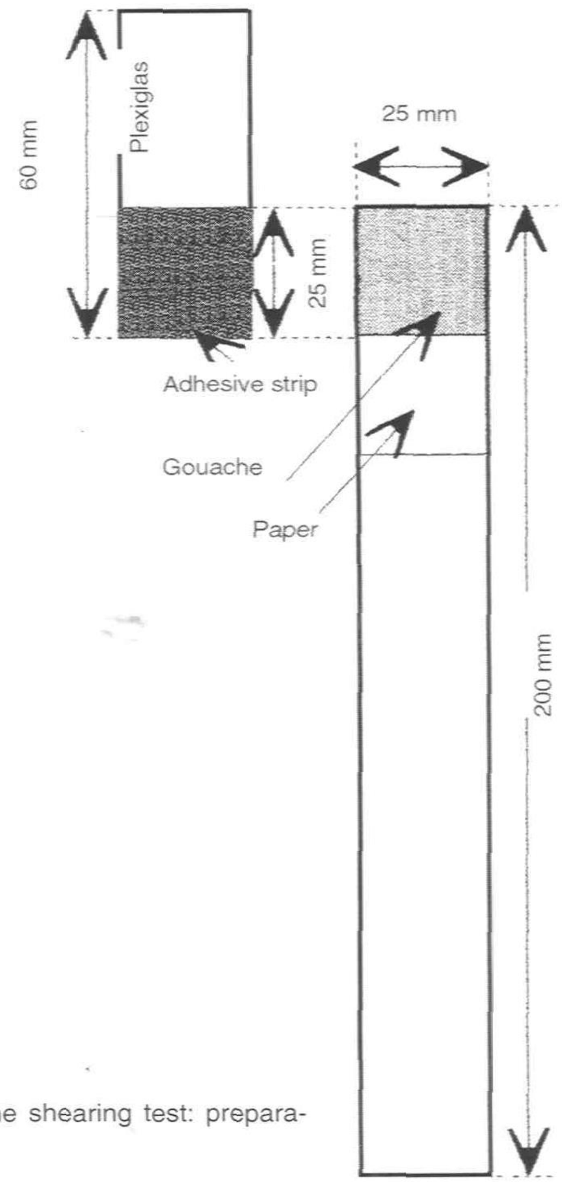

Fig. 2: Scheme of the shearing test: preparation of the sample.

The peeling test for adhesion

This test aimed at measuring the adhesion of the gouache after consolidation. It was developed in 1995, for a study on the *Consolidation of painting on wood of the Brittany Parliament in Rennet.*
The peeling test samples consisted of two pieces of paper stuck onto a Plexiglass (Fig. 1) plate at a distance of ca. 3 mm from each other, using an araldite glue. One of these areas was to be consolidated, while the other was used as a control sample. For each strengthening agent, we prepared three sets of samples: two layered blue, two-layered red and red on blue, as described above.

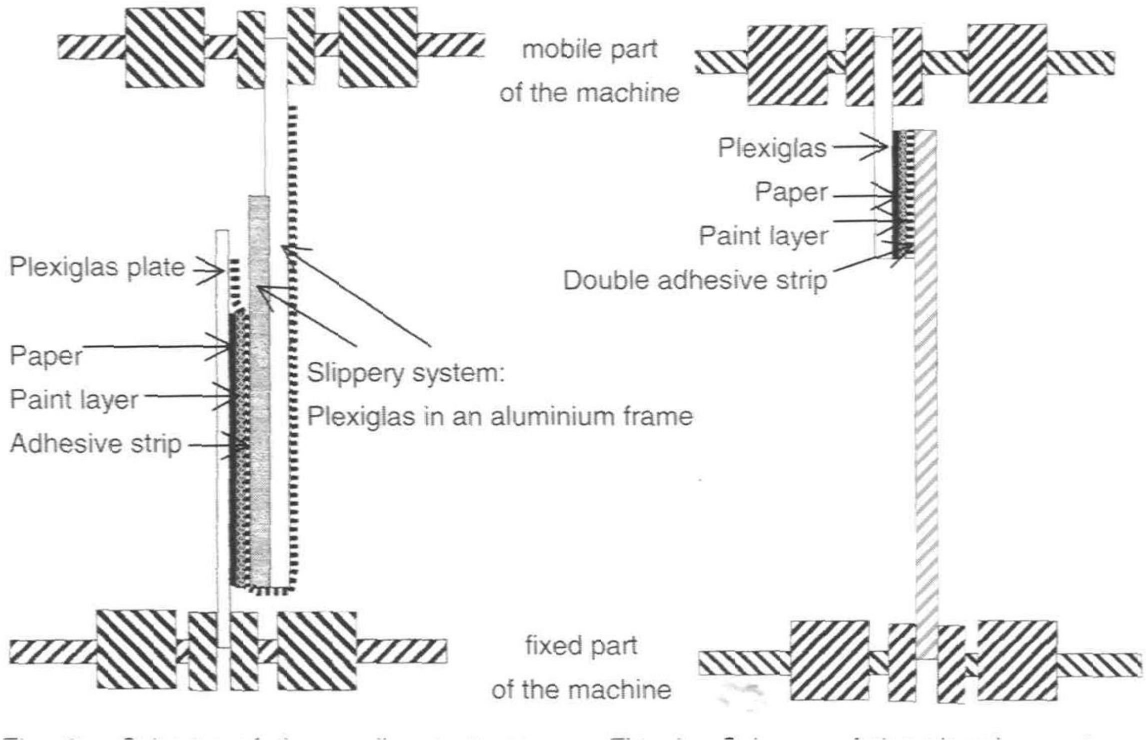

Fig. 3: Scheme of the peeling test: arrangement of the sample in the machine
Fig. 4: Scheme of the shearing test: arrangement of the sample in the machine

After drying, the samples were stored in a dry oven at 60°C for three weeks. After two further weeks of drying at room temperature, the different fixative solutions were applied on each sample using a brush. Only one half of each sample was consolidated, the other half being used as a reference.
To make sure that a constant force was applied to each sample, we used the tension machine described above. First, a strong adhesive strip was applied on the whole sample. The fixed grip of the tension machine supported one end of the sample, while the movable grip held the long end of the strip, peeling it with a constant speed. To ensure that the adhesive strip was unstuck evenly, a mobile Plexiglas plate maintained it slightly against the gouache (Fig. 3). This plate slid into an aluminium frame, in which the sample was inserted.
After detaching the adhesive strip, the peeled gouache area was measured, both for the consolidated and the unconsolidated area, using a transparent film ruled in 2 mm^2 squares. The greater the peeled-off area, the less the adhesion.

The shearing test of cohesion

This test aimed at measuring the cohesion within the paint layer and its adhesion to the paper after consolidation[9]. For this purpose, we tried to break the cohesion of the gouache by applying a uniform force vertically to the whole gouache layer. The shearing test samples consisted of 25 x 25 mm painted areas applied on 50 x 25 mm paper strips. Each piece of paper was glued onto a 200 x 25 mm steel plate (Fig. 2). For each strengthening agent, we prepared five samples of each of the three kinds described above (blue, red, red on blue). One set of five samples was kept unconsolidated for reference. The red on blue layered samples were not submitted to accelerate ageing because of their high fragility. The other samples were aged at 55°C and 75% RH for four

weeks. After one further week for reconditioning to room temperature, the consolidant was applied using a brush.
For the test, a Plexiglas plate was stuck directly onto the paint layer (Fig. 2) using a strong, double-sided adhesive strip. The fixed part of the machine supported the sample, while the movable part pulled the Plexiglas plate, stuck on the gouache, with a constant speed (Fig. 4). The different break areas were then measured with a transparent film ruled in 2 mm^2 squares.

How the gouache looked before and after consolidation:

After drying, cracks appeared very quickly on all samples.
- The blue gouache (diluted with 10% distilled water) was slightly matt and rather porous. Its network of cracks was large and not very dense.
- The red gouache appeared to be slightly shiny, its cracking was rather dense.
- The two-colour samples appeared at first very fragile. The upper red colour lost its sheen and became as matt as the blue gouache. The two types of cracking also appeared on the red layer: small and dense cracks specific to the red paint, together with large and spaced cracks caused by the underlying blue colour.

Visual modifications induced by the strengthening agent and observed in raking light, differed with the porosity. The appearance of a matt and rather powdery gouache will be less altered than that of a thick and shiny gouache. However, all strengthening agents change the refractive index. The change in visual appearance also depended on the strengthening agent. Gelatine tended to produce more shiny filaments; any concentration of methylhydroxyethylcellulose filled the cracks, giving the appearance that they had been levelled out; polyvinylic alcohol 1% darkened the cracks of the blue gouache, while the 4.25% (viscosity 3 cP) of Paraloid B72 gave the gouache a slight sheen.

INTERPRETATION OF THE RESULTS

The peeling test was a first attempt to classify the different strengthening agents. It was not very reliable, because each strengthening agent was only tested on one sample. However, it could be done quickly and easily and it allowed two main product families to be distinguished (see below).
The shearing test was much more reliable. Each strengthening agent was tested on five samples each of the three types of paint layer. The visual appearance of the five samples of the same composition and using the same consolidant turned out to be very similar. Moreover, it became obvious that the results were as would be expected knowing the physical properties of the different strengthening agent.

Characteristics of the strengthening agents

Depending on its surface tension, a strengthening agent can interact with the gouache in two ways. If it flows deeply into the cracks, then it "penetrates" the paint layer. If it flows more quickly, but less deeply, then it "diffuses". The first, i.e. penetration, improves the adhesion of the gouache on the paper, the second, i.e. diffusion, increases the internal cohesion of the paint layer. The action of a strengthening agent is also influenced by the characteristics of the gouache, mainly its porosity and the presence of flakes or cracks.
Obviously, and as our tests suggest, an aqueous strengthening agent with a high surface tension and a high viscosity does not diffuse through an homogenous paint layer very well, while a highly porous gouache allows better diffusion. If there are cracks, then penetration is improved, whether the gouache is porous or not. Thus, an aqueous strengthening agent can produce good cohesion between the flakes.
Non-aqueous strengthening agents behave differently. They present a weak surface tension and a low viscosity. Therefore, they diffuse quite well, but do not penetrate the gouache deeply. A porous gouache makes penetration easier, allowing greater diffusion (see Table 3).

Concentration (%)	Gelatine	Sturgeon glue	Polyvinyl alcohol	MHE cellulose	Paraloid B72
3			44.27		24.25
2.5			40.80		24.63
2			45.81		24.82
1.5			48.07	52.66	24.75
1	61.1	61.46	51.69	66.06	25.32
0.5			52.83		25.58

Table 3: Surface tension (mJ / m^2} of different concentrations

As mentioned above, two families of strengthening agents were distinguished: highly viscose aqueous products, such as the methylhydroxyethyicellulose, and non-aqueous products with a low viscosity / low surface tension, such as the Paraloid B72. The other products fell between these two extremes, depending on their concentration. The characteristics of gelatine and sturgeon glue solutions in the concentration used for this experiment were very similar to those of the methylhydroxyethylcellulose solution (sturgeon glue having a lower viscosity), while the polyvinyl alcohol solutions were closer to those of Paraloid B72.

The peeling test for adhesion

After the test, the consolidated and unconsolidated peeled areas were measured with a transparent film ruled in 2 mm^2 squares. This is the unit for the peeled and non-peeled areas. To determine the efficiency of a strengthening agent, we divided the peeled area of the consolidated part of the sample by the peeled area of the reference part. This ratio is called the "consolidating power" of the product[10]. If it was equal to one, then the peeled areas were the same and therefore the strengthening agent had not improve the gouache cohesion. If the ratio was less than one, then the strengthening agent had some effect: the smaller the consolidating power, the more efficient the strengthening agent. Finally, a consolidating power greater than one indicated that the product actually weakened the paint layers (Fig. 5).

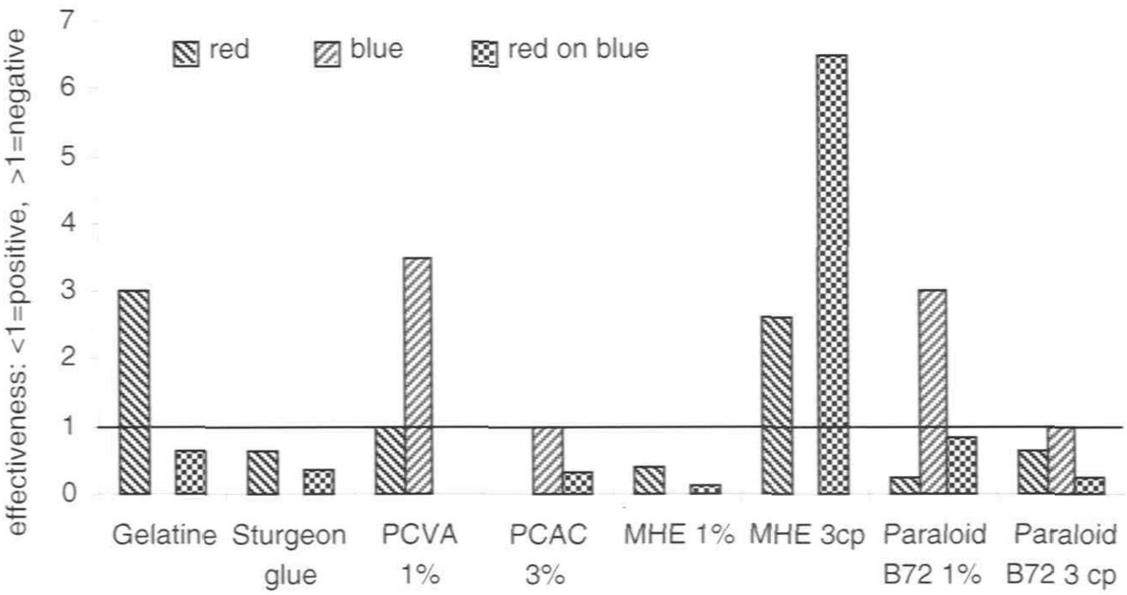

Fig. 5: Effectiveness of the consolidants (see below).

It can be seen that the aqueous strengthening agents with a high surface tension and viscosity weakened the adhesion of the non-porous gouache. Indeed, the many cracks in this kind of paint were not sufficient to ensure the total and homogeneous penetration of the viscous solution to the paper. On the other hand, the solutions with poor surface tension (polyvinyl alcohol and Paraloid B72) weakened the adhesion of the porous gouache. Their wide diffusion enhanced the cohesion of the gouache, strengthened its upper layer, but not to the layer which was adhered to the paper.

The shearing test of cohesion

Analysing the shearing test results three kinds of break became obvious: a flaking of the paint layer, a cleavage between the paint layer and the paper, and a tearing of the paper. Very often, these three levels of breaks were present simultaneously on the same sample (Fig. 6).

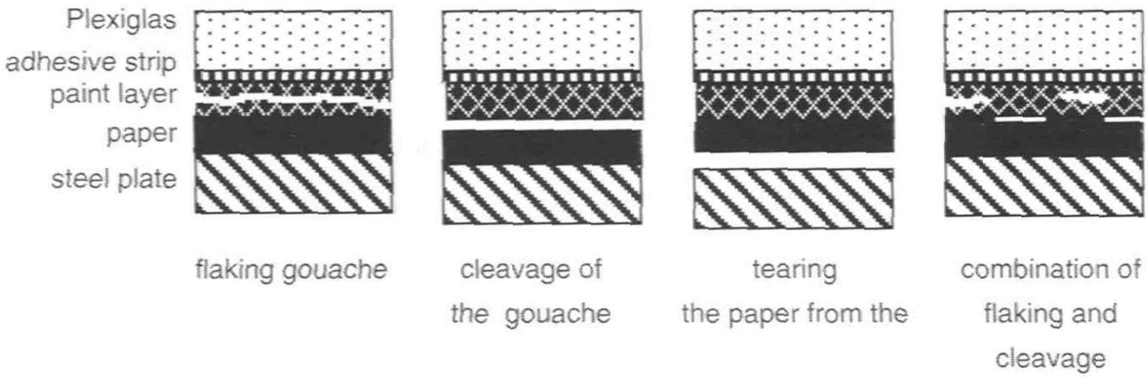

Fig. 6: Scheme of different kinds of break.

As with the previous test, the area of each kind of break was measured with a transparent film ruled in 2 mm^2 squares. Comparing the relative area of each level of break allowed us to determine the efficiency of each strengthening agent.
Most of the breaks observed revealed a loss of cohesion within the gouache layer. A strengthening agent which caused this type of loss was considered unsuitable and therefore its use rejected. In some cases however, the gouache layer resisted the traction and we observed a tearing of the paper. This characterizes a good strengthening agent.

A loss of cohesion: flaking of the gouache

Flaking gouache is a total or a partial loss of the cohesion and adhesion of the paint layer. A strengthening agent, which penetrates the first layer of the gouache uniformly enhanced the cohesion and the adhesion of the gouache.
If we compare the surface area of the three kinds of break, we notice that the one associated with areas of flaking was generally the lowest. There were never more than ca. 270 mm^2 damaged in this way (43% of the whole painted area = 625 mm^2; see Fig. 7, while the cleaved areas (Fig. 8) represented nearly 90% (560 mm^2) and the areas where the paper had been torn (Fig. 9) nearly 80%. We noticed that the most viscous strengthening agents did not reduce the flaked areas: they seemed to remain on top of the paint layer and barely diffused. Moreover, they were the cause of local tensions between the consolidated areas and those which were weaker. On the other hand, some very volatile strengthening agents did not prove to be very efficient when applied to the porous gouache: the solvent evaporated too quickly, and the consolidating resin did not have enough time to penetrate the gouache layer deeply enough. Finally, we noticed that the polyvinyl alcohol and Paraloid B72, both at 1%, tended to lower the flaked surface area of a cracked, non-porous gouache

layer. These strengthening agents have a low surface tension; they diffused well through the paint layer and enhanced its cohesion.

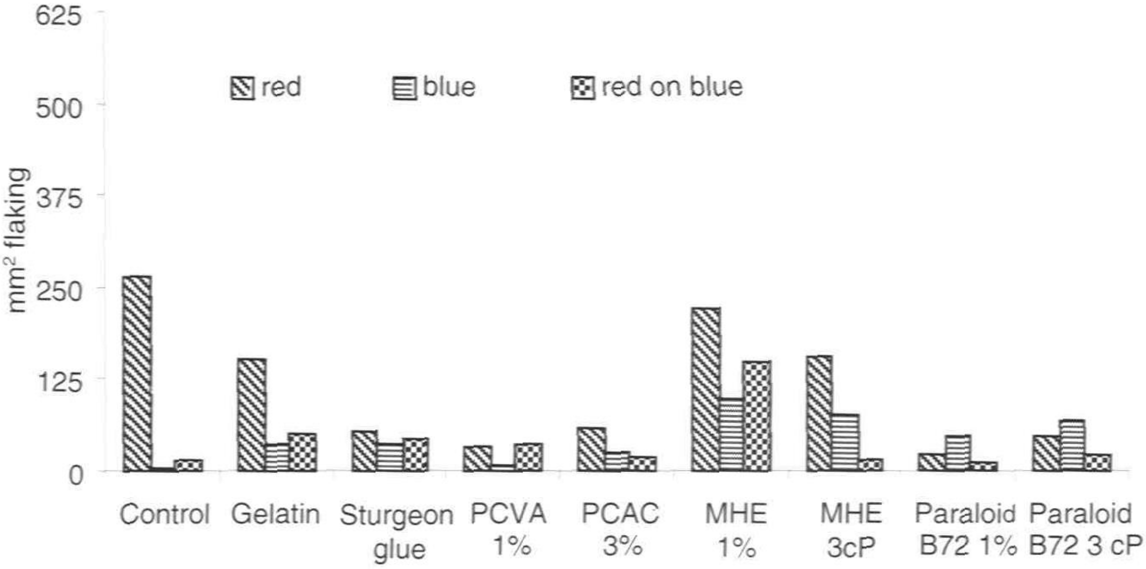

Fig. 7: Results of the shearing test for cohesion: flaking.

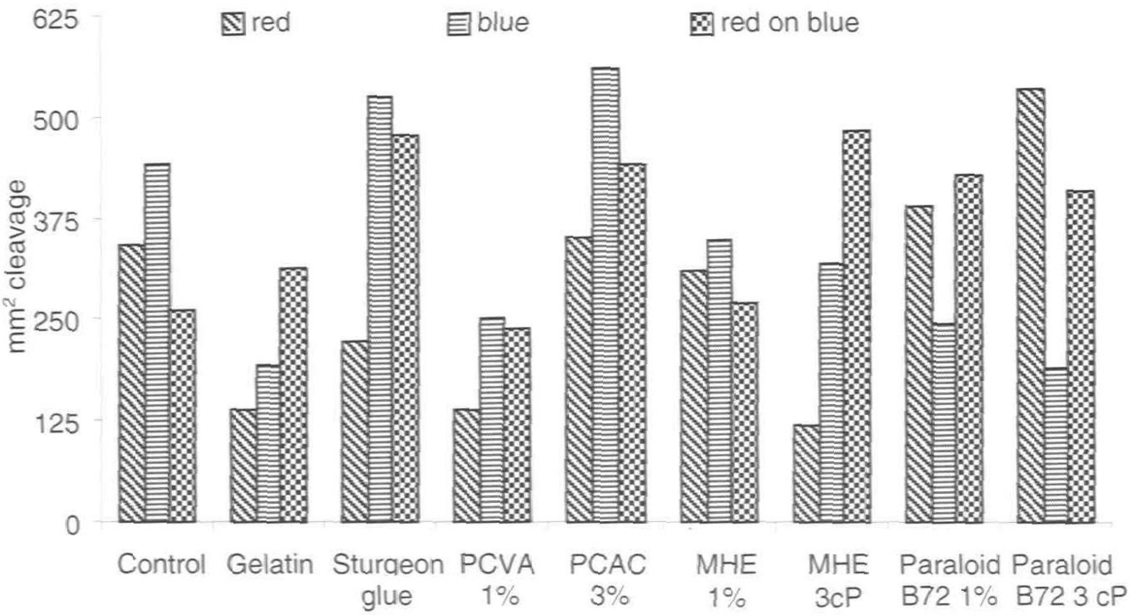

Fig. 8: Results of the shearing test for cohesion: cleavage.

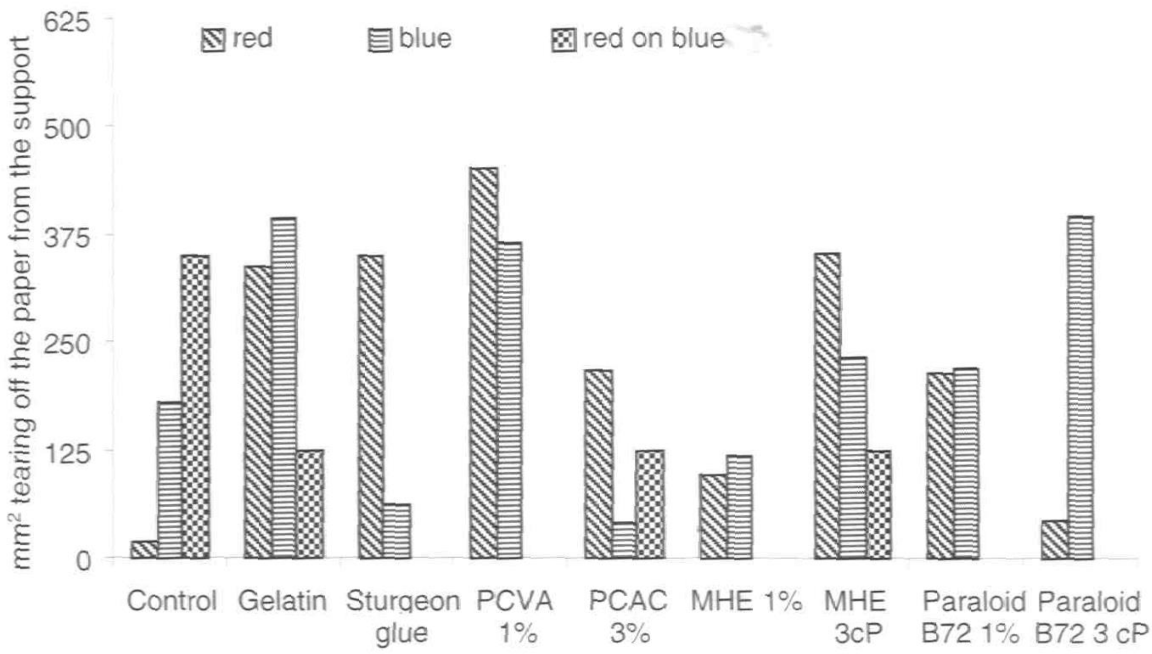

Fig. 9: Results of shearing test for cohesion: tearing off the paper from the support.

Loss of adhesion: the cleavage between gouache and paper

Cleavage is a break between the paint layer and its support as a result of loss of adhesion between them. The paper appeared to be slightly coloured by remains of pigment. A cleavage revealed that the cohesion of the gouache was stronger than its adhesion to the paper.

Throughout the test, the cleaved surface areas were the most common and conspicuous damage. Quite remarkably, for many strengthening agents the cleaved areas on the consolidated samples were larger than those on the control. The improved cohesion of the gouache seemed to fail on its adhesion to the paper.

Actually, the cleaved surface area depended on the colour of the gouache. The unconsolidated control showed that the blue gouache cleaved more easily than the red. This can be explained by the blue gouache having a low content of binding agent.

The 1% solution of polyvinyl alcohol presented the best improvement, i.e. the fewest cleaved areas, for all type of gouache (Fig. 8). This strengthening agent has qualities both of aqueous and also of products with low surface tension. Its weak surface tension gave it good diffusion, which prevented the flaking. On the other hand, being aqueous, it penetrated rather deeply into the paint layer.

A good adhesion and a good cohesion: tearing the paper from the support

If the paper was torn from the support together with the paint layer, then there was good cohesion of the gouache and good adhesion between paint layer and paper. In this case a large tearing area characterised a good strengthening agent: it showed that the product lowered the tendency of the gouache to flake and to cleave.

Of the control samples, the two-colour samples presented the largest areas where the paper was torn from the support, the blue gouache the second, and red, which was the most fragile, the smallest.

It is interesting to see that all strengthening agents consolidated these red samples quite well. The 1% polyvinyl alcohol gave the best results for the two one-colour samples, but provided or at least maintained adhesion between the two colours layered on each other. Generally the best result was given by the gelatine; it improved or at least kept the adhesion of each kind of paint layer.

CONCLUSION

Our tests highlighted the characteristics of each strengthening agent (Table 4) and can help to select the most suitable one. Polyvinyl alcohol at 1% clearly enhanced the adhesion and reduced the probability that the gouache would cleave or flake. Its effect on the two-colour gouache, however, was quite disappointing. The methylhydroxyethylcellulose at low viscosity (3cP) enhanced the gouache adhesion for die single- and two-layered samples; it did not improve their cohesion, and sometimes even weakened it. Gelatine was a good strengthening agent for flaked gouache and also improved the adhesion, which has already been observed by others". We observed, however, that it did not diffuse very well, and therefore it seemed not to be a good adhesive for the powdery gouache. This kind of gouache needed a strengthening agent which was good at diffusing in order to improve its cohesion.

Table 4: Several characteristics of the strengthening agents at different concentrations.

	Concentration (%)	viscosity (cP)	surface tension (mJ / m²)	Adhesive index	Penetration	Diffusion	Optical aspect
Gelatine	1	3.07	61.1	+++	+++	–	+
Sturgeon glue	1	1.5	61.1	+++	+	++	–
Polyvinyl	1	1	51.69	++	+++	++	–
alcohol	3	3	44.27	++	++	++	+++
MHE	1	24.64	66.06	+	–	–	–
cellulose	>0,5	3	72.8	+	++	–	+
Paraloid 572	1	1.4	25.32	+	+	+++	+++
	4.25	3	24.25	++	+	++	+++

Gelatine:	Good adhesion of the one-layer gouache
Sturgeon glue:	Cleaveage of porous gouache; good adhesion of glossy- and low-porous gouache
Polyvinyl alcohol 1%:	Enhanced the adhesion of the one-layer gouache
Polyvinyl alcohol 3%:	Cleavage gave good cohesion of glossy gouache
MHE cellulose 1%:	Increased flaking of two-layered, porous gouache
MHE cellulose >0.5:	Increased flaking of porous gouache irregular penetration
Paraloid 572 1%:	Good penetration of the porous gouache
Paraloid 572 4.25%:	Good penetration of the porous gouache

To choose the right adhesive for our special case, we also had to consider how each strengthening agent would resist ageing. The chemical stability of polyvinyl alcohol[12] in the presence of pigments and that of Paraloid B72 when applied on paper is not proved; so these two were rejected. Finally, we decided to use gelatine to consolidate the gouache paintings made by Claude Autant-Lara. This strengthening agent gave the second best results in terms of cohesion and adhesion (ranked just after the polyvinyl alcohol), and at the same time it absorbs and desorbs atmospheric water in an amount comparable to that of the paint layer, so that there will be no or only little internal tensions. A non-aqueous strengthening agent such as Paraloid B72 could induce microscopic tensions in the flakes, blocking the movements of the paint during its exchanges with atmosphere. Thus, we concluded that gelatine, over a long period, would be the safest and most appropriate strengthening agent.

Finally, we would like to emphasize, what is probably the most important conclusion of this study, that adding a strengthening agent is an irreversible operation, which in some cases can actually

weaken the paint layer. An improperly chosen strengthening product can induce tensions in the gouache layer, and reduce its internal cohesion and/or its adhesion to the paper.
It must also been taken into consideration that for the tests a long fibred paper was used, which improves the adhesion. Therefore, our conclusions on how each strengthening agent can improve the adhesion may be too optimistic for gouache on paper of a lesser quality. In many cases, especially if no flakes are noticeable, it seems safer to keep cracked gouache painting in the best climatic conditions and under optimum mechanical protection rather than consolidate it. If it appears that the gouache layer has flaked to such a degree that it should be consolidated, comprehensive tests should be performed, because the choice of best strengthening agent depends strongly on the physical properties of the gouache, and the paper in any given case.

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