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Backing Munch – past and recent attachment of Edvard Munch's monumental Aula paintings to rigid supports

Introduction

In 1916, the University of Oslo (UiO) received an important art donation for its main Assembly Hall, The Aula, in the form of a monumental decorative scheme painted by Edvard Munch.[1] This remains the only room decoration by Munch to have been preserved in its original context. The scheme consists of eleven large scale paintings dating from 1909 to 1916 and with the two largest, *History* and *Alma Mater*, measuring approximately 4.6 x 11.6 m. The paintings are executed in oil paint on eighteen separate pieces of canvas and they are unvarnished,[2] covering an approximate surface area of 220m².

Since their installation in 1916, the Aula paintings have been subjected to a history of different structural treatments and cleaning programs.[3] They were taken down only 10 years after their initial hanging due to heavy soiling. Their surfaces were cleaned and reverse sides coated with a water-soluble mixture of chalk, zinc and lead white and the canvases were reattached onto new stretchers. During the spring of 1940, the eleven paintings were crudely cut out from their niches in the walls (removing the original tacking edges), rolled up, and stored for safe keeping during the course of World War II. Their post war re-hanging of 1946 led to all eleven pictures being further cut down in size[4] and glued onto 4-5 mm thick masonite boards using a rye flour paste adhesive.[5] These masonite sheets were joined together and strengthened by a timber framework to the reverse. Extra insulating glass fibre mats were also attached between the timber boards and the reverse sides were covered by sheets of brown paper glued to the framework. The marouflage materials used in the two largest paintings, helped to increase their total weight up to approximately 450 kg.

In 2006, The Munch Aula Paintings Project (MAP) [6] was launched, and it soon became evident that the wooden framework had created a series of problems; notably, the concave and convex warping of the painted surfaces, acute flaking paint and visible cracks running through the paint and ground layers down to the canvas support (figure 1). This, in turn, had resulted in the nails used for fixing the framework to the masonite boards having begun to push outwards towards the front of the paintings. They were pressuring the verso of the canvases and with time could risk piercing through them.[7] In addition, the wooden structure had functioned like a cold bridge[8] producing a re-occurring pattern from dirt accumulations on the paintings' surfaces. Finally, the paintings' wall attachment fixtures had started to fail.[9]

The recent backing treatment[10] for the Aula paintings coincided with the total renovation project of the building itself to mark the 200 year anniversary of the University of Oslo in 2011. It's time scale was thus determined by the government's funding of the building renovation spanning from 2009 to 2010.[11] The paintings were first dismounted and transported to a temporary studio. Due to their rigid masonite supports the canvases could no longer be rolled and transported out of the building. A special door had to be created for the evacuation of the larger paintings. This is located in the middle of the north wall behind

1 Detail of *Men Reaching towards the Light* showing a typical tear and bulk in the canvas, flaking paint and a number of paint losses. These were caused by movements in the wooden framework behind the masonite from 1946. Photographer: Mirjam Liu, January 2011.

2 The new door (5,6 x o,55 m) during opening at night. Photographer: Karen Mengshoel, March 2011.

the main painting entitled, *The Sun* (figure 2).[12] The eleven paintings were then surface cleaned, parallel to the continued in-depth investigations concerning the condition of the paint surfaces and Munch's techniques. The structural conservation treatment was carried out in 2010 and all the eleven paintings were returned to the Aula during the beginning of 2011.

Alternatives for structural conservation

A pilot-project carried out during 2006-2008 revealed a wide variety of limitations and options relevant to proposed conservation treatments. The condition of the paintings appeared to be similar across the eleven works and the artist seems to have also used the same type of materials and techniques in all. Standard methods using temporary paper facings together with an aqueous adhesive could not be used to protect the paint surfaces due to Munch's painting techniques. Another aspect that helped to dictate the nature of treatments employed was the sheer size and weight of the art works in question. The logistical and practical constraints concerning lifting and turning the canvases meant that the conservators would have to rely on professional movers[13] and specialised equipment[14] for basic handling throughout the course of their conservation.
Another constraint to the project was importance of keeping the Aula Hall's current acoustic value.[15] This implied that the paintings were to keep their same mass per area ratio (kg/m^2) if any materials were to

be removed or replaced.[16] The now defunct 1946 wall attachment fixtures exposed the need for a new re-hanging solution with an improved and reversible system.

The pilot project produced three different options concerning possible structural conservation methods:

> *Option 1: To keep the existing semi-rigid backing support system from 1946 (masonite and timber framework).*

This was regarded as the least invasive approach as well as the least time consuming. Another benefit was that the acoustic quality would remain the same. It would, however, require the need of an additional four-edged frame anchored into the wall so as to make a new and better wall attachment support for the paintings. The depth of niches could easily accommodate such a frame and this solution would increase the air gap between the reverse side of the marouflage materials and the wall. In addition, the edges could be sealed off to prevent a draft, thus improving the overall insulation behind the paintings. Increased insulation could probably reduce the dirt pick-up but it would not prevent the continued structural movements in the paintings supports caused by the Hall's fluctuations in relative humidity (ranging from 8-80% RH.[17]). Numerous disadvantages outweighed the benefits such as; the localised de-lamination between the canvas and masonite supports, the risk of nails piercing through the canvases, increases in cracks, and the possibilities of further paint loss. In addition, this option would not solve the unstable concave and convex warping of the paintings' supports.

> *Option 2: The removal of the masonite marouflage and the re-lining of the original canvases.*

This would regain a canvas painting's appearance and eliminate the disturbing concave and convex warps. Any additional textile support (including new stretchers, possible interleafs/inlays and layers of adhesive) would not necessarily alter the acoustic quality of the Hall so long as the lining materials had the same kg/m^2 mass ratio as the 1946 marouflage. Nevertheless, a return to a flexible support would require an increased dependence on stable environmental conditions, a standard which is often difficult to achieve in listed and historic buildings. Another disadvantage would be the actual physical intervention of the marouflage reversal. All backing materials would have to be carefully removed including the mechanical removal of the hardened glue paste residue from the reverse side. This procedure typically employs a tough and complete temporary protective facing so as to avoid the risk of damage incurring to the paint layers.[18] In addition, five of the paintings were made from two pieces of textile and one from three. The lack of original canvas seams and seam hems, helping to keep the edges together, would also have to be considered. Finally, if all the paintings should be treated simultaneously and within the limits of a two year working period, this approach would require access to a substantially larger working space (500-600 m^2) [19] as well as a larger crew of conservators.

> *Option 3: The addition of a rigid support to the existing marouflage.*

This alternative would essentially help increase the rigidity of the existing supports and minimise the possibility for further warping. A more flexible indoor climate would also be permisable in comparison to the other two options presented. The method would only require the removal of the 1946 wooden frameworks (including paper and insulation) avoiding any direct contact to the reverse of the canvases. The acoustic levels would remain unchanged as the kg/m^2 mass ratio difference could be re-calculated back to the same level through the new secondary reinforcement materials. Disadvantages included the need to have all paintings face down, but for a much shorter time and with less risk of damage as in option 2. The question of a temporary protection of the paint surfaces would also pose an important challenge.

After much discussion, option 3 was chosen for further investigation.

3 Material requirements and test panel

The option of adding a second and more rigid support to the existing marouflage entailed demands to the qualities and characteristics of the materials that would be used, both temporary and permanently. In addition, "try-outs" had to be performed on a test panel to ensure that the procedure was viable.

The vulnerable nature of Munch's unvarnished paint (easily stainable colours and ground) influenced the need for a localized, temporary[20] protective facing in the form of a non-aqueous product with minimal solvent components, which would be both easily applicable and removable and without dirt cleaning properties during removal. Cyclododecane[21] was considered as an option, being an organic compound which at room temperature sublimates from a solid to a gas without a liquid phase. Extensive tests were carried out recording the rates of sublimation at two different room temperatures 16° C and 23° C. The sublimation rates of cyclododecane covered with foam (the same type was used as local facing when the paintings were laid face down) versus uncovered cyclododecane areas, melt (60° C) and mixed applications (1:10 cyclododecane to white spirit), and its application on absorbent and non-absorbent grounds were tested and recorded. Further tests were also performed on absorbent grounds with some dirt accumulation in order to investigate if cyclododecane would have an effect on the appearance of the surface after sublimation. The general results from the tests showed that the un-covered samples at 23° C sublimated noticeably faster than the covered samples at 16° C. The difference between them being approximately 2 weeks to 1 month for the complete sublimation at 23° C, depending on the thickness of application, compared to 1-3 months at 16° C, again depending on the thickness of application. Cyclododecane as a melt and as a mixture with white spirits adhered well to absorbent grounds but was less effective on non-absorbent grounds since it tended to break off more easily. Lastly, the tests showed that cyclododecane would not have an effect on the appearance of the slightly dirty surface after sublimation. In relation to the Aula paintings, the samples tested at 16° C and covered resembled the more realistic scenario since the paintings would be face down. Equally, cyclododecane, both as a melt and as a mixture, could likewise be applied as facing on the paintings as it would sublimate in time before their reinstallation in the Aula Hall.

The list of requirements for the new rigid support was extensive; the material had to be inert, stable, flame and water-resistant, contain no volatile or metallic components, have an increased stiffness, have good thermal insulation properties but keep the same thickness and weight ratio as the existing wooden framework and the insulation.[22] In addition, it had to be produced on large scale, so as to minimize the number of joints, and there had to be holes through the new panels to prevent air pockets occurring between them and the masonite during the gluing procedure. A 30 mm thick honeycomb board was suggested by the company AIM Composites Ltd (hereafter AIM)[23] with a core structure of aramid fiber paper and surface skins of woven glass cloth impregnated with heat-resistant phenolic resin.[24]

Similar stringent demands were also set for the main marouflage adhesive. The glue had to be applied cold and without any use or emission of heat. It should not emit any volatiles during the final preparation in the studio, or during its application or setting. Curing should involve low pressure and only have an open working time for at least 2 hours with a minimum setting time of 24 hours. In addition, it should have some gap filling capacity, high stiffness (good binding capacity) and stability close to Feller's class A > 100 years. After extensive testing on samples of masonite, a two-component modified epoxy, Aerok ® 2100,[25] was chosen.[26] Joining of honeycomb panels was proposed using a two- component epoxy resin.[27]

For any extra local gluing necessary during the process, Araldite ® AY 103/HY991,[28] was also suggested, having a low-viscosity and being easily spreadable. It could also be applied with a syringe through the holes in the honeycomb, filling possible voids between masonite and honeycomb after the main marouflage process.

The purpose of the test panel was to examine the suitability between the previously marouflaged paintings with that of the new attachment procedure as well as the new materials chosen in collaboration with AIM. The semi-rigid support of masonite and framework was constructed from two sheets of masonite held together by a wooden framework similar in construction and dimensions to the 1946 marouflage. The framework was also positioned so that all the edges as well as the joins between the masonite sheets were covered. A rye flour glue was used and small headed tacks were nailed in a similar fashion as in the original paintings. A piece of canvas, half the size of the smallest of the Aula paintings, was prepared on both sides with a mixture of chalk, zinc white and animal glue to simulate the paintings' original ground layer and the 1926 preparation layer on the reverse. The canvas was then marouflaged with a mixture of rye flour and animal glue[29] onto the masonite boards. The adhesive between the canvas and masonite were applied with a flat spatula (not toothed as was used in 1946). Heat and pressure were then applied with a commercial iron through brown paper from the front of the test painting. This procedure is likely to have been the same as when the original paintings were marouflaged as residues of brown paper imbedded in the paint layer were found on some of the paintings. Considerable heat, 150-200° C, and applied pressure were necessary to fix the canvas to the masonite. Small de-laminations were observed where the adhesion was poor due to the lack of pressure or failure of the rye flour glue. The test painting was then left to dry for one and a half months. When the test panel had cured it was turned face down on to sheets of foam[30] laid out on the floor, simulating the method for how the new marouflage would be applied with regard to the sheer size of the actual paintings. The wooden framework was then removed (see paragraph 4), the reverse of the masonite prepared, and the new marouflage materials attached to the reverse (see also paragraph 4). After curing, the test panel was then cut in to several pieces so that the efficiency of the bonding between the masonite and honeycomb could be assessed (figure 3). The immediate results showed that the marouflage process of the test panel was unsuccessful with large areas of visible delamination between the two materials. The reason for this was not due to the materials or process but rather caused by an uneven floor. Since both the foam sheets and the masonite are malleable materials they formed closely to the contours of the uneven floor in contrast to the stiff and level nature of the honeycomb panels. This meant that either, a greater amount of pressure was necessary in order to counteract the uneven nature floor or, that the working floor itself had to be leveled out. It was considered unsuitable to exert more pressure since this would put the original paintings under an unacceptable amount of stress and the working floor had thus to be leveled as evenly as possible. In addition, the slight gap filling ability of the adhesive, required the new leveled floor to ideally have no more than 1 mm deviation per meter. This is a standard that was difficult to obtain since the highest class of Norwegian floor leveling is less even than this, but a definite re-leveling was necessary before the working floor was acceptable for the proposed treatment.[31]

3 Visual examination of the test panel with a double marouflage after being cut. Photographer: Karen Mengshoel, April 2010.

Structural treatment 2010

Prior to the structural treatment of the paintings in 2010 several other actions were carried out, such as the removal of the paper and insulation materials to the reverse sides and the consolidation of flaking paint and surface cleaning of the painted surfaces. Munch's use of a lean oil paint mixture combined with large areas of exposed ground and no varnish influenced the choice of dry-cleaning methods against using solutions due to the risk of staining.[32]

The paper and insulation to the reverse sides were detached right after the paintings were transported to the temporary studio as these materials could emit dust and hazardous glass fibers into the working areas. The paintings were then surface cleaned with latex free polyurethane[33] sponges. During cleaning, isolated ar-

4 Detail of *Alma Mater* showing stripes of local facing with cyclododecane in areas that correspond with masonite joins. Photographer: Karen Mengshoel, September 2010.

5 Reverse side of the masonite attached to *The Sun* with holes and gaps leveled with commercial fillers. Photographer: Karen Mengshoel, June 2010.

eas of flaking paint was consolidated with 3% sturgeon glue solution in distilled water. Consolidation was performed during cleaning and not prior since this was the most effective due to space and time constraint.

The characteristics and condition of the original painting techniques led to the decision to choose cyclododecane as the non-aqueous material for the temporary facing. Two different solutions of cyclododecane was used as a protective facing to sensitive areas on the paintings such as, high impasto, areas with cracked paint and areas above the masonite joins (figure 4) where there were risks of movement after removal of the framework. For the most part cyclododecane dissolved in white spirits (1:10 cyclododecane to solvent) was preferred because this solution had longer working time and good handling properties. In some of the paintings the solution created haloes[34] in the absorbent paint and ground. This meant that the facing material had penetrated deeper into the painting structure than expected and would therefore take longer to sublimate. In these areas cyclododecane was applied as a melt instead of as a solution.

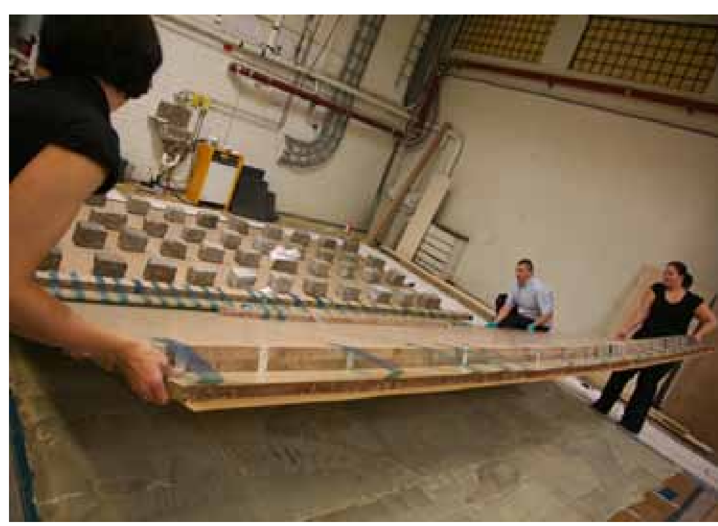
The next step involved placing the paintings face down onto sheets of foam over a large sheet of Tyvek (larger than the painting) on the newly leveled working floor (see also paragraph 3). Preparation of the reverse sides involved removal of the wooden framework, extractions of nails and preparation of the masonite. The framework was cut into smaller pieces (approximately 5 x 3 cm) with a circular saw to ease the removal. As a safety margin, the circular saw was set to stop a few mm before reaching the masonite and the job was then finished by hand with a fine toothed saw. One single strong tap with a mallet dislodged the wooden framework, limiting the amount of vibrations.[35] The paintings could now no longer be moved as they were only held together by the rye flour layer between the canvas and masonite boards. With regard to an emergency they could be moved by pulling the Tyvek sheet along the floor underneath the foam.

After removal of the framework and the nails, the masonite's surface had to be prepared prior to the attachment of the new and additional support. It was imperative that the masonite's surface was as level as possible due to the limited gap filling properties of the chosen adhesive. Raised areas were sheared off with a sharp scalpel or knife and any small indentation were filled with commercial fillers.[36] Larger holes in the masonite, like screw holes from previous attachment to the niches, were taped with masking tape since these holes were too large to be filled. The whole reverse surface was then sanded down with a fine sandpaper to remove any excess filler as well to ensure a good grip for the gluing (figure 5). This process of leveling and sanding was repeated several times until the correct level surface was acquired. Lastly, the masonite was vacuumed and cleaned with isopropanol.

The edges of the painting had to be prepared so as to safeguard that no adhesive would spill over the edge and adhere to the canvas (which in some areas was larger than the masonite) and the painted surface itself. A silicone adhesive release tape[37] was used to mask off the edges, approximately 5 mm in over the masonite, with the rest of the tape adhered to the silicone release paper (figure 6). Any spillage would then run down the silicone paper and not onto the foam which could risk it coming into contact with the paintings surfaces.

6 Detail of the reverse side of *Alma Mater* showing the masking with a silicone release tape and paper to avoid spillage of the marouflage adhesive on to the surface of the painting. Photographer: Karen Mengshoel, September 2010.

Preparation of the honeycomb panels consisted of a light sanding of the contact surface and cleaning with isopropanol. Due to the sheer size of the paintings, five of the eleven required for the honeycomb panels to be attached in sections.[38] These were joined together with a tongue and groove join (figure 7) with tape on one side of the open tongue so as to ease the process. Prior to the final gluing, dry fit tests of the new honeycomb supports were performed. These were carried out to insure correct alignment and because it would be very difficult to move the honeycomb panels on the masonite after the adhesive had been applied.



7 The second marouflage in progress showing cobbelstones and the honeycomb panels' groove while joining. Photographer: Karen Mengshoel, September 2010.

Both the honeycomb panels and masonite were first cleaned with isopropanol to remove any residue of dust or grease before the gluing. Due to the open working time of the adhesive (approximately two hours) the whole marouflage process had to be performed in one session. This meant that at least five conservators had to be present during the whole process. One person performed the measuring of the two-components adhesive,[39] one mixed the components thoroughly, another poured the adhesive onto the masonite and two persons spread the adhesive on the masonite with tooth edged spatulas (these were constructed so that 2 mm ridges of glue were left on the masonite). The new panel was then positioned on the masonite and pressed down by the weight of two persons crawling on top of it, and the alignment of the panels were continually checked by measuring the distance between the edges of the masonite and the edges of the honeycomb panel. Five of the largest paintings meant that at least two honeycomb panels had to be joined together during the gluing process. In these cases, one panel was positioned first before the adhesive was applied to the second section. The second panel was then positioned (see figure 7) and the join in the honeycomb panel was glued together (with the second two-component epoxy glue[40]) and the process repeated until the whole painting had been marouflaged.

After gluing and positioning all of the honeycomb panels the structure was weighted down with cobblestones[41] (see figure 7) and left to dry overnight. The stones were removed and the surplus of adhesive on reverse of the honeycomb panels removed with chisels. Non-destructive testing with Bondascope 3100 (an ultrasonic [pitch catch] bond tester from NDT Systems)[42] was performed by AIM in order to check the bonding between the honeycomb panels and the masonite (figure 8). Areas with dis-bond were then filled with a low viscosity two-component epoxy[43] using a syringe through the holes in the honeycomb panels. After a couple of hours the panels were again checked with the Bondascope 3100 to establish reduction of dis-bond between the honeycomb and the masonite. The new marouflage was then left to cure for about one week before the painting could be moved away for storage.

8 The non-destructive testing with Bondascope 3100 on the reverse side of the honeycomb to test for dis-bond between the first and the second marouflage panel. Photographer: Karen Mengshoel, September 2010.

Installation 2011: attachment and framings

Due to the loss of the original stretchers and the wasting of the second stretchers in 1946 from the 1926 campaign, no information could be traced concerning the paintings' initial and second wall attachments. The post war installation consisted of long screws (approximately 42 for the largest paintings and 16 for the smallest ones). These screws were located along the edges of the paintings, going through 5-7 mm wide predrilled holes piercing the paint structure, canvas and masonite and secured into small squared wooden blocks wedged in to the mortar of the brick wall. The majority of these wooden blocks had become loose and could no longer provide a permanent attachment for the paintings.

During the building renovation, a wooden framework of Norway spruce (*Picea abies*) (consisting of 148 mm wide and 22 mm thick boards with 100 mm long self-tapping screws[44]) was secured along all edges of the picture niches to provide an even, straight and vertical background basis (figure 9) for the recent re-installation of the paintings.[45] In order to simplify the re-attachment of the Aula paintings, sections of the volute wall capitals on each side of the niches, were converted into detachable sections (figure 10).

The edges of the honeycomb and any superfluous masonite was trimmed down to match the individual di-

9 Detail of the new wooden frames along the edges of the picture niches for the attachment of the paintings. Photographer: Mirjam Liu, December 2010.

10 Detail of a volute wall capital made detachable to simplify new and future detachment and re-attachment of the paintings. Photographer: Mirjam Liu, February 2011.

mensions of the niches prior to the final installation. A protective U-shaped aluminium profile frame[46] was glued on to the exposed honeycomb edges with a two-component epoxy resin.[47] This framing system was chosen to provide solid support for the final fixing screws,[48] to increase the rigidity of the marouflaged paintings, to improve their handling properties and to seal the open edges of the honeycomb. In some areas, where the fit might be tight,[49] an aluminium tape was used instead of the aluminium frames.[50] Since the marble shelves, along the lower edges of the niches were uneven, the paintings were leveled out by using several wooden and plastic wedges.

The paintings' original picture frames had not survived, but an archival photo revealed slim, semi-rounded wooden borders with a glossy surface.[51] This could have been the first frame from 1916, or that from 1926 when the paintings received new stretchers. After the masonite backing of 1946, these frames were replaced with 3-5 cm wide strips of zinc pinned to the edges of the paintings and painted with colours which presumably matching the pictures at that time. The decision was to replace the existing framing system with a more appropriate solution.

The new framing system consist of c. 300 m of seamless glass fibre picture frames (4 cm wide and 3 mm thick) (figure 11) attached with Velcro[52] pre-fixed to the aluminium frames.[53] They hide the gaps between the paintings and their surrounding marble as well as the stucco work, The frames also provide protection for long and narrow stripes of pristine areas of Munch's colours having minimal contact with the room's atmosphere. These areas will give valuable information for future examination on how the atmosphere may change Munch's materials. In the narrow areas where these frames encroached slightly over Munch's paint, a protective woolen felt tape was inserted. Prior to their attachment, the picture frames were painted with a matt, light grey colour in keeping with the main colours of the marble surrounds.[54] The choice of Velcro allowed for their easy removal and avoided introducing screws or nails.

11 Detail of the new picture frame. Photographer: Karen Mengshoel, April 2011.

Future risks and prospects

As previously mentioned, the weakest layer of the double marouflage remains within the attachment between Munch's canvases and the masonite panels. A recent FTIR analysis of the adhesive suggests a carbohydrate (rye flour) and protein (glue) composition. In November 1945, 1717 kg of masonite and 10kg of Venice turpentine were imported from Sweden for the Aula marouflage.[55] The turpentine was probably added to the rye flour glue paste to act as a plasticising agent. This plasticising effect of Venice turpentine is likely to have been short-lived.[56] As a consequence, it may have resulted in an increase in the stiffness of the adhesive and might have also increased its acidity. Masonite, which contains cellulose, lignin and sometimes small quantities of alum, is also likely to turn acidic during aging. At present there exists relatively little applied research concerning the aging of masonite panels although it has been used extensively in Swedish marouflage practices during the 20th century,[57] and as painting support by many artists since the 19th century (alongside other types of wood-fibre boards).[58,59] Recent pH measurements of the Aula masonite boards gave a near neutral result, and the alkaline chalk present on the reverse side of the canvases (preparation treatment from 1926) might have prevented the acidification of both the masonite and the rye flour paste.[60] The individual manual skills required for a successful glue-paste lining are seen as crucial[61] and according to Arthur Lucas, the average paste lining will last for less than 100 years.[62] If this is the case, then the Aula rye flour paste adhesive is expected to have 30 more years left. There are however several Italian examples of paste lining durations exceeding 200 years.[63,64] To our knowledge, there is no on-going research which examines the nature and aging process of these long lived treatments.

At present, the attachment between the masonite and the original canvas is generally good. Visual surface examinations in raking light combined with fingertip touches (causing a diverging, hollow sound) have revealed that all the paintings suffer from small and local de-laminations between their fabrics and the wood-fibre boards (figure 12).[65] Above some of these voids the paint had started to flake, at worst with minor losses. It is clear that movements in the wooden framework had been responsible for some of these detachments, but far from all since there are several which are located elsewhere and in a random manner. Blind cleavages in the support structure can cause continuing damages on a microscopic level, such as micro-cracks in the paint layers that will lead to further cracking and finally more flaking paint. If the voids also are expanding in scale, it is essential to know the reasons and at what rate. The randomly located de-laminations between the original support and the masonite can have different causes, but there are no visual or tactile evidences of their age. They may have occurred at once during the mounting campaign in 1946, for instance due to uneven applications of rye flour adhesive, or because of local shortages of sufficient pressure or heat. Or they can have been formed later on, for instance as a result of climatic changes in the Hall (from c. 8 to 80% RH) followed by changing temperatures (within indoor limits). During the Aula project, none of the observed de-laminations seemed to expand in size and no new ones were detected, but we cannot exclude that such changes might not occur. If they are caused by an on-going decomposition of the paste, this process has to be monitored on site. If the de-laminations will proceed, they also have to be understood better to enable discussions on future treatments and to predict if or when the 65 years old marouflage paste will start to fail in larger areas.

12 Detail in raking light of de-lamination between canvas and masonite. Photographer: Mirjam Liu, October 2010.

13 Metigo Map of *Women Reaching towards the Light* showing the areas of de-laminations (yellow) between canvas and masonite. Illustration by Mirjam Liu, October 2010.

Possible interventions can be minimal invasive as local regeneration or re-consolidation of the adhesion or maximal as removal of the materials in the two marouflages. Local re-attachment between the canvas and the masonite will be a challenge because of the sensitive and absorbing ground which is easily stained by water and most organic solvents. This approach will demand tests on how to apply suitable and adequate portions of non-staining glue into the de-laminations and from the front of the paintings. Fast evaporating organic solvents might not stain the original materials, but this also requires tests. The adhesive has to be low-viscous to be inserted locally to the voids through the paint layers and canvas threads and with a thin syringe (which inevitably will leave small holes, although invisible for the Aula audience c. 7-3 m below), but its viscosity will also be crucial due to the strong capillary forces in the absorbing ground and canvas.

A maximal future approach will require removal of all the materials of the two marouflages as well as an additional structural treatment either including a third marouflage or a first lining campaign. In 1951, a similarly marouflaged Munch painting of 4,80 x 11,50 m called *The Scientists* (in Norwegian: *Alma Mater/Forskerne*)[66] were manually pulled off from its masonite boards while the canvas was simultaneously rolled on to a large roll.[67] Prior to its display at the Munch-museum, the canvas was re-attached to a new stretcher.[68] Furthermore, other methods used for removing masonite from canvas paintings have also been described by late 20th century authors.[69,70]

Removal of masonite as well as honeycomb still is an option subsequent to the recent marouflage, nevertheless not without risks of posing immense stress followed by possible damages to the paint layers. On the other hand, if the latter is being solved, such removals may also include a possible re-use of the honeycomb, either as marouflage or as substitute for new stretchers if the paintings are being lined to a new canvas (and then stretched over the honeycomb). A re-use of the long lasting honeycomb (including compensation for the loss of the weight of the masonite) will not change the acoustic claim of maintaining the same mass per area. But again, an exceedingly time consuming removal of the rye flour paste layer from the reverse side of the canvases has to be performed both for a third marouflage and for a future lining.

Meanwhile, there are also ways of minimizing any potential increase in the de-laminations between masonite and canvas through preventive conservation. Natural glues and pastes have strong dimensional responses to fluctuations in humidity. At very low RH levels, an adhesive like hide glue develops high forces.[71] From 80% RH and above, hide glue has no strength and no ability to maintain its bond.[72] In the Aula, and prior to the building renovation, the RH has reached 80% RH during the summer seasons due to the routine of open doors for visiting tourists. This cannot continue and the University of Oslo must find better alternatives for this open door activity. According to the new guidelines for museum-environments, it is important to keep the historic indoor climate environment unchanged if it has not proven to be harmful.[73] The only acceptable changes are improvements that reduce damaging fluctuations,[74] as the high RH-values during the summer months must have represented up to the recent building renovation.

Recommendations for future maintenance and research

After the treatment and re-hanging of the 11 paintings in the Aula Assembly Hall, aspects concerning maintenance, environmental monitoring and future research will be considered. These will ensure that the best possible practice and routines are implemented for covering all areas including the daily cleaning of the Hall and its surfaces.

Infra-red recordings of the walls were carried out prior to the last removal of the paintings and also before they were re-installed. This form of analysis will be conducted again as soon as the outdoor temperature is low enough. Comparative recordings like these hope to enlighten conservators on the actual surface temperature of the paintings and any potential consequences as a result of a sudden or drastic change.

Despite the introduction of additional backing materials to the reverse sides of all the paintings, the paintings will still have to be periodically assessed for any possible localized delaminating pockets forming between the 1946 masonite boards and the original canvas supports. This could be the result of a possible degradation of the glue layer as well as an evelated RH above 80%. Such areas have already been recorded manually (by fingertip touches) (figure 13) and would need to be compared to more precise methods, such as a portable nuclear magnetic resonance mobile universal surface explorer (NMR-Mouse).[75] The use of this more accurate and specialized measuring equipment might also provide insight into the nature of the failing adhesive (from 1946) and influence the conservation treatment response.

Future inspections of the de-laminations will also be achieved by new visual examinations under raking light. The visual information provided can be directly compared with the initial Metigo-mapping images.[76] Additional recording techniques for the structural conditions of paintings; either with NMR-Mouse,[77] terahertz images (TeraHertz imaging)[78] or flash thermography,[79] which will be considered as monitoring tools, if suitable and able to be used in-situ on a scaffold.

The aim of the recent project has also been to facilitate the accessibility to the paintings in terms of evacuation and future conservation treatments, thus the paintings have become easily detachable.

Abstract

The conservation, research and practical challenges concerning Edvard Munch's 11 monumental canvas paintings from the University of Oslo's Aula Assembly Hall are presented with reference to their history of previous treatments from 1916. The evaluation of the existing masonite marouflages resulted in the adhesion of extra lightweight honeycomb structures to the reverse sides. An in-depth description of the choice of practical treatments, methods, consultants and use of specialist materials are described in relation to the physical considerations when dealing with monumental canvases. The issue of the Hall's acoustic parameters, the evacuation considerations for the paintings and recommendations for monitoring, maintenance and re-examination in the future are also discussed.

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2 As many other large scale paintings after the late 1880s. Jirat-Wasiutynski, V. and Travers Newton Jr, H. (1998) Absorbent grounds and the matt aesthetic in post-impressionist painting. *Painting techniques, history, materials and studio practice. Contributions to IIC Dublin Congress 7-11 september 1998*, 235-239.

3 Frøysaker, T. (2007) The paintings of Edvard Munch in the Assembly Hall of Oslo University. Their treatment history and the Aula-project. *Restauro* 4, 246-257, 266.

4 Including loss of false seem hems in six of them. Five of these paintings are made of two piecec of canvas and one is made of three pieces. The other five paintings are painted on one textile and have no seems.

5 The content of this marouflage glue never was reported or mentioned except for its rye flour component. In 1974, one of the marouflage participants, Bjørn Kaland, listed three paste recipes for marouflage: I) 125g rye flour, 50g glue and 3,5dl water; II) 50g animal glue, 75g rye flour, 75g wheat flour, 25g Venice turpentine, 25g syrup, 25g crushed linseed, 600g water and 15g alum and finally, III) 5kg wheat flour, 2,5kg rye flour, 2kg glue in solution (1:10), 1 teaspoon alum and 200g honey. Kaland, B. (1974) Klisterdublering. *Dublering av lerretsmalerier. Rapport fra konserveringsseminaret 6-10 mai 1974 i Nasjonalgalleriet*, 38-45.

6 http://www.hf.uio.no/iakh/english/research/projects/aula-project/index.html (15.01.2011). MAP was two part, the pilot project 2006-2008, the treatment part 2009-2011.

7 Illustration no. 10, p. 48, in Frøysaker, T. and Liu, M. (2009) Four (of eleven) unvarnished oil paintings on canvas by Edvard Munch in the Aula of Oslo University. Preliminary notes on their materials, techniques

and original appearances. *Restauro* 1, 44-62.

8 See figure 15, p. 254, Frøysaker 2007.

9 Illustration no. 18, p. 255, Frøysaker 2007.

10 This structural treatment was first reported by Frøysaker at the ICOM-CC Paintings Group Workshop: Current practice and Recent Developments in the Structural Conservation of Paintings on Canvas Supports, in Vantaa, Finland, 16.09.2010.

11 The conservation campaign 2009-2011 was funded by Technical Department, UiO.

12 Mengshoel, K. Liu, M. Moltubakk Kempton, H. and Frøysaker, T. (2012) Moving monumental Munch: From listed building to temporary studio – and back (accepted for IIC Nordic Group –NKF's XIX International Conference, 15–17 October 2012 Oslo, Norway).

13 Exel Fine Art (DHL Qality Cargo), Oslo, the only Norwegian transport company which is a member of ICEFAT: http://www.icefat.org/ (16.03.2011).

14 Hoisting crane, semi-trailer, pallet truck, lifting jack, schaffolds, pulleys, straps, chains and hooks.

15 The room's acoustic is considered to be of world class for classical chamber music.

16 Which was advised by the acoustic specialists.

17 These variations in RH were measured by Jeremy Hutchings, IAKH during 2006. The building renovation could not include improvements like RH control since the building has no dampproof course.

18 Ford, T. (1996) *The conservation of 18th century portrait of Dr.Mead, involving the reversal of a plywood Marouflage,* M.A. Research Project, University of Northumbria, 30-35. See also Hangleiter, H.M. (1987) De-restoration of large sized paintings consolidated by marouflage, *Zeitschrift für Kunsttechnologie und Konservierung*, 105-9.

19 Since the paintings cover c. 220 m^2, a parallel preparation of the lining supports would require the same floorage to be added and both actions would yet need more space. Preferably, the studio should be close to the ground level and have a 5 m tall entrance and ceiling.

20 Feller's class T (temporary use).

21 Rowe, S. and Rozeik, C. (2008) The uses of cyclododecane in conservation, *Reviews in Conservation*, No. 9, 17-31.

22 To find the individual weight for the different materials samples were taken from the 1946 marouflage and weighed to calculate their specific weight. Then these number were multiplied to match the individual sizes for each painting. Finally, the results were rechecked by weighting a couple of the smallest paintings (*Chemistry* (c. 4,5 x 2,25 m): 85 kg and *Women Harvesting* (c. 4,5 x 2,25 m): 85 kg). The combined weights for the framework and the insulation did correspond tho the proposed and chosen weight for the new honeycomb and its main marouflage adhesive.

23 AIM's homepage: *http://www.aimcomposites.com/* (01.07.2011).

24 AIM's Flitelam GN2 honeycomb panels were manufactured to meet all the requests including the demand for negligible volatile emissions and high bond strength, and they were fully cured at 135°C before usage. The maximum panel size with no joints for the Aula paintings are 2,4x1,2 m, but they vary from painting to painting. Their expected service lives are close to 100 years. AIM can produce panels without joints up to 3,6x1,5 m.

25 Aerok® 2100 is produced by Forgeway and distributed by AIM.

26 The shear stress of the bond-line between AIM's selection of adhesives and samples of masonite was tested (with a Lloyd EZ-50, their universal material testing machine). This type of Aerok is a two-component modified epoxy; its expected service life in extreme conditions is close to 100 years; the curing takes 2 hours at 20°C to harden and 7 days ambient was suggested to achieve its maximum strength. AIM's tests also showed that it can be applied with a tooth-edged spatula which will share out a 1 mm thick layer of glue after hardening.

27 Epoxy resin: Aerok ® 9170 : A: 1050601 and B: 1030502 (hardening agent). Usable life: 20-30 minutes. Curing time: 1 week. Expected service life is close to 100 years. Produced by Forgeway and distributed by AIM.

28 Araldite ® AY 103/HY 991 is produced by Hunstman Advanced Materials and distributed by AIM. Its usable life is ≥ 90 minutes at 23°C; its curing time is 150 hours and its expected service life is close to 100 years.

29 This recipe for the rye flour glue was 125 g rye flour mixed with 50 g animal glue dissolved in 3 L of water. It originated from conservator Bjørn Kaland (see note 5). He participated in the first marouflage of the Aula-paintings and this recipe also reflects the inventory of material purchased for the marouflage in 1946.

30 Fireflex ® S305.

31 Through discussions with AIM, we decided to accept a maximum of 10% dis-bond between masonite and honeycomb. This is too small to affect the attachment of the new marouflage. After the final floor leveling, the amount of dis-bond proved to be less than this.

32 Frøysaker, T. Miliani, C. and Liu, M. (2011) Non-invasive evaluation of cleaning tests performed on "Chemistry" (1909–1916), a large and unvarnished oil painting on canvas by Edvard Munch. *Restauro* 4, 53-63.

33 Daudin-Schotte, M. Bisschoff, M. Joosten, I. van Keulen, H. and van den Berg, K.L. (2010) Dry cleaning

approaches for unvarnished paint surfaces, *Cleaning 2010. New Insights into the Cleaning of Paintings*. Eds. Fuster-López, L. Charola, A.E. Mecklenburg, M.F and Doménech-Carbó, M.T., 51-53. See also: http://www.scribd.com/doc/28005037/Painting-Dry-Cleaning-Table (30.05.2011).

34 The haloes appeared as a darker rings of saturated ground and paint around the area with cyclododecane.

35 The nails had very small heads and therefore the majority of them were extracted when the blocks of wood were knocked off the masonite. Those that were not extracted in this way were pulled out with the use of thongs.

36 The commercial filler used was mainly 'Jotun lettsprakel' medium. This filler is based on derivates of cellulos mixed with fillers and finely ground dolomit marble. Two other commercial fillers (Gjøko lettsparkel medium and Nordsjö lettsparkel LS104) were also tried but they did not have as good working properties as Jotun lettsparkel medium. These were based on latex.

37 Flashbreaker ® produced by Tygavac and distributed by AIM.

38 *Awakening Men in The Flood of Light* and *Spirits in The Flood of Light* got two sections, *The Sun* (and also *Women Reaching towards the Light*, but for another reason) three and *History* and *Alma Mater* five.

39 Aerok ® 2100. See note 25.

40 Aerok ® 9170. See note 27.

41 The amount of weight per m^2 was about 22 kg. There were between 30 stones on the reverse side of the smallest paintings and up to 185 stones on the largests.

42 http://www.ndtsystems.com/Bond_Testers/BondaScope_3100/bondascope_3100.html (16.03.2011).

43 Araldite ® AY 103/HY 991. See note 28.

44 Type: HUS Universal screw, 7,5x100mm (TXI 40). Supplier: Motek.

45 The brick wall was given a coat of water glass (silicate of potassium) to reduce dust emission.

46 The aluminium profile is 38,05 mm high and 14,15 mm deep (external measures).

47 Aerok ® 9170. The same resin was also chosen for the joints in the honeycomb panels. See notes 27 og 40.

48 Type: assy 3.0 panhode aw20 elz. N 4,5x60. Supplier: Würt. Screws for the paintings' attachment to the wooden wall-frames, c. 50 for the two largest paintings and c. 15 for the smallest ones.

49 At the top corners of each painting and along the two sides of *History*.

50 *History* was too wide for its niche to give room for aluminum frames and these honeycomb edges were closed with aluminum tape. Here the screw holes from 1946 were re-used for attaching the picture to the wall frame.

51 Illustration no. 27, p. 58 in Frøysaker and Liu 2009.

52 Type: Dual Lock 3M.

53 As a security measure, a few small and thin screws fixed the picture frames to the aluminium frame in the upper sections and in the higher corners of all the paintings.

54 Paint on picture frame: Nordsjö Heftgrund V, S2002-Y (NSC-code).

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64 In Galleria Doria Pamphilj and The Borghese Gallery there are many paintings which were lined with paste between 1760 and 1790 as well as during the beginning of the 1800s (the latter was the activity of the Cecconi-Principe). Some of these linings have never been removed. Personal communication with Matteo Rossi Doria (16. and 23. September 2010).

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aspx?id=79&mid=76 (07.03.2011).

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68 Again without removal of the marouflage paste from 1946 which continued to cause conditional problems.

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74 It is hoped that the new heating system will reduce the risks for low RFs during the winter seasons. It includes water central heating system with under-floor heating in the Hall, convector heaters along the sides of the stage and higher temperature in the Hall's surrounding rooms, of which some used to be quite cold (the attic, basement, entrance etc.).

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