INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE

ISSN: 2067-533X Volume 13, Special Issue 1, December 2022: 1643-1652 www.ijcs.ro

MECHANICAL LOADS ON MUNCH`s POROUS PAINTINGS CAUSED BY HANDLING DURING IN-HOUSE TRANSPORT

Eva STOREVIK TVEIT[1,*], Semih GONEN[2], Emrah ERDURAN[2]

[1] MUNCH Museum, Edvard Munchs plass 1, 0194 Oslo – Norway
[2] OsloMet – storbyuniversitetet, postboks 4, St. Olavs plass, 0130 Oslo – Norway

Abstract

Loose paint, which occurs in Munch's paintings after exhibitions caused by mechanical loads during transport, handling and storing in deposit or exhibitions, is a recurring challenge and a major concern. An essential feature of many of the Munch paintings in the MUNCH collection is the porous and brittle paint layers with weak cohesive and adhesive properties. In this paper, we present some initial measurements of the accelerations that cause mechanical loads that act upon such paint layers during handling in-house on trolleys. This study is a part of a larger project that aims to investigate the effect of vibrations on fragile paintings during in-house transport, storing on screens and the impact of sound in exhibitions. The main objective is to determine acceptable vibration levels, and develop methods to reduce the damaging vibration and shock loading. In doing so we will manage to optimize ROS-analyses and develop more reliable preventive strategies.

***Keywords**: Mechanical loads; Vibration; Shock; Porous paint; Sound; Trolleys*

Introduction

The MUNCH collection, like many other collections worldwide, experiences a large increase in requests for loans. Hence, the number of paintings at exhibitions outside the museum has increased significantly over the last years. In addition, with the new MUNCH building in Oslo, the number of exhibited paintings and other arrangements like concerts and museum nights has also increased. Consequently, the risk of damage to the paintings during transport, handling and storing in deposit or in exhibitions is higher. Therefore, the need to protect the museum's collections from shock and vibrations that affect the paintings during preparing, handling, storing and transporting for exhibitions is a high priority.

An essential feature of many of Munch´s paintings in the MUNCH collection is the porous and brittle paint layers with weak cohesive and adhesive properties. A great majority of the paintings are not varnished, but all the paintings are glazed and protected with stiff backboards before exhibitions. In addition, most of them are protected with cushioning foam, felt, or both, to protect them from the impact of shock and vibrations. The multi-layered system applied is chosen based on earlier research [1]. Nevertheless, loose paint observed on Munch's paintings after exhibitions remains a concern.

The damage in canvas paintings caused by shocks may be immediate and evident, like visible loose paint, while it may also be invisible to the conservators. Failure in the adhesive and cohesive bonds between paint layers can occur after repeated cycles of vibration leading to paint loss. Similar to vibrations, shocks can also be detrimental to the cohesion between the

* Author for correspondence: estveit@munchmuseet.no

paint layers. For example, if the painting is transferred on trolleys in-house with repeated bumps and thresholds on the ground, several cycles of shocks can be recorded within a single trip. Since the strength of the paint layers is weak in many of Munch's paintings, even small shocks or a few repeated vibration cycles may cause damage. As such, damage to Munch's paintings due to mechanical loads caused by vibrations and shocks is a common problem art conservators at the MUNCH face relatively often.

Damage caused by mechanical loads has been investigated in several studies. Among these, several focused on damping systems for paintings in crates for transportation in trucks and by airplanes [2-9]. The effect of vibration from building constructions in exhibitions has also been introduced in some papers [10-11]. Kracht has compared two different suspension systems, steel hook and nylon rope, on paintings mounted for the exhibition where they were exposed to vibrations from visitors and car traffic [12]. She has also investigated three different grid walls and five different canvas mounting systems on paintings in storage. There has been some attempt to define acceptable vibrations limits [13-16], but as Saunders wrote in 1998: "*Because of the lack of information on the effect on "real" paintings, it is not possible to define safe limits for shock and vibration*." [6]. There is little actual knowledge on which levels of vibrations cause damage to artworks, but The British Museum reported in a paper from 2000 that damages to fragile artworks from vibrations are in the range of 0.2 to 0.6g. These damages, however, occurred in previously known weak areas of the artworks [13]. In addition, research focused on the vibration of the natural frequencies of canvas painting [2], and on the vibration behaviour of canvas dependent on weathering [19]. Investigations concentrated only on transferring paintings on trolleys are missing, but there is an example of simulated transport of crates on trolleys [20]. Finally, procedures to protect artworks from damage caused by vibrations induced by construction activities [21] were suggested.

In an ongoing project, MUNCH and Oslo Metropolitan University aim to record the extent of shock and vibrations and investigate how shock and vibrations influence canvas paintings during in-house handling and transfer on trolleys. All exhibitions outside the MUNCH and, to an almost equal extent, exhibitions in-house, require that each painting is transferred on trolleys from the screens in the storage to the conservation areas then, after treatment, to photo areas and finally to the packing room. The same procedure happens when the painting returns to the museum, increasing the risk of damage to paintings due to repeated shocks and vibrations.

The focus of this paper is to present the results of the initial measurements of shock and vibrations on trolleys in-house at the old Munch Museum as presented at the conference MUNCH2022 at MUNCH in Oslo. The article is structured as follows: First, the experimental study was conducted and summarized in detail, followed by an in-depth discussion of the results of the experimental campaign. The main conclusions drawn from the study and a summary of the open challenges remaining in the field of mechanical loads and their impacts on canvas paintings conclude the article.

Experimental part

Shock Measurements

The paintings were transferred on five different trolleys (Table 1). These trolleys were transported on different routes in-house in the old Munch Museum. The routes had several thresholds and bumps in the floor.

The initial shock measurements were performed using the instrument Testo 184 G1 as seen in figure 1, with triaxial acceleration sensors that have a measurement range from 0-27g and accuracy ± (0.1g+5% of mV) ±1/1m/s^2, where g is the gravitational acceleration (1g = 9.81m/s^2) and mV is milivolts. Only shocks passing 4g could be read exactly in time while shocks below 4g were only recorded in number during the whole measurement time. The instrument was attached to the platform of the trolleys with and without foam.

Table 1. Summary of all the trolley transports

Trolley	Thresholds ranged from highest to lowest	Number of trips	Shocks recorded over 4g
Small, 79cm length, 65cm width, 155 high from platform, 40kg, no foam, small wheels, 1.6cm rubber, Ø8 cm, no foam	Thresholds storage, exhibition area, photo studio and into elevator. Elevator needed in all routes.	7	26
Small, 79cm length, 65cm width, 155 high from platform, 40kg, no foam, large wheels, Ø12, 2 cm thick rubber part.	Thresholds storage, exhibition area, photo studio and into elevator. Elevator needed in all routes.	9	16
Small, 79cm length, 65cm width, 155 high from platform, 40 kg, blue foam (LD 33, 1cm), large wheels, Ø12, 2 cm thick rubber part.	Thresholds storage, exhibition area, photo studio and into elevator. Elevator needed in all routes.	9	13
Large, 130cm length, 87cm width, 185 high from platform, 85kg, no foam, large wheel, Ø12, 2cm thick rubber part.	Thresholds storage, exhibition area, photo studio and into elevator. Elevator needed in all routes.	9	2
Large, 130cm length, 87 cm width, 185 high from platform, 85kg, blue foam (LD 33, 1cm), large wheel, Ø12, 2cm thick rubber part.	Thresholds storage, exhibition area, photo studio and into elevator. Elevator needed in all routes.	4	0

Fig. 1. From left: Small trolley, small wheels, without foam. Large trolley with foam, angle twin unit walls, large wheels,Ø12, 2 cm thick rubber part. Small trolley with foam, singe unit wall, large wheels, Ø12, 2 cm thick rubber part, Testo placed in corner on the width.Testo placed in the corner at the long side on small trolley. Small and large wheels.

By using the same art technicians to handle the trolleys, we managed to control the speed of movements to similar levels for each transfer. During the shock measurements, the trolleys were lifted over the thresholds to reflect the general practice at the old Munch Museum. All the measurements were done when transferring the original paintings, and the routes covered all the usual transport stages on which the paintings are transported in the museum. Each route was measured from four to nine times, depending on the different floors and the obstacles on the route so that all the possible routes and obstacles were covered several times with the different trolleys.

Vibration Measurements

At the old MUNCH building, a series of experiments were conducted using the small trolley with large wheel and foam. The effects of trolleys crossing the bumps created by the door thresholds on the acceleration levels of the picture frames were measured. The measurements were repeated with two different frame sizes. The frames were carried without attaching them to the trolley, as this is the common practice employed in the museum. Three tri-axial MEMS digital acceleration sensors and 20-bit low noise data acquisition systems were used in all experiments. Two sensors, one at the bottom and the other at the top, were placed on the outer frame of the paintings and one directly on the trolley, as shown in figure 2. The sampling frequency was configured to 500Hz and the acceleration time-histories were recorded throughout the experiments. A total of 16 trips were conducted on different routes by the same art technicians so that the speed of the travel, and the lift and push over the bumps were consistent. Ten of the 16 trips were made with the small frame, whereas the remaining ones were with the large one. The routes were between the storage, conservation studio and exhibition area.

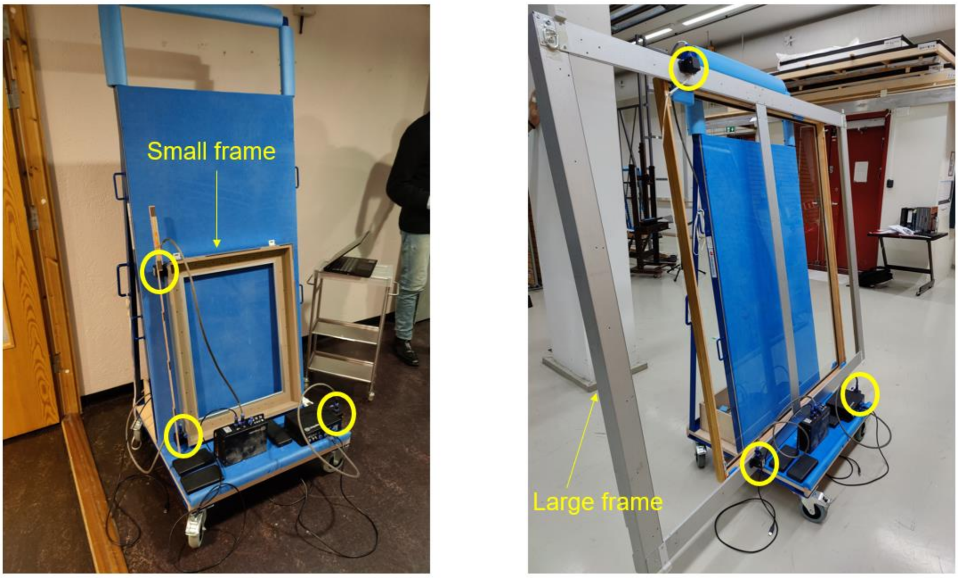

Fig. 2. Small and large painting frames and the instrumentation setups on small trolley with large wheels

Table. 2. Summary of the trips.

ID	Frame	Route	Notes	Number of trips
1	Small	Conservation studio - Storage (round trip)	Trolley lifted	3
2	Small	Conservation studio– Storage (round trip)	Trolley not lifted	3
3	Small	Storage - Exhibition	Trolley not lifted	3
4	Small	Storage - Exhibition	Trolley is lifted	1
5	Large	Storage – Conservation studio	Trolley not lifted	3
6	Large	Storage - Exhibition	Trolley not lifted	3

Here it should be noted, that, due to the high mass of the accelerometers available, it was not possible to measure the vibrations on the canvas directly. As Chiriboga writes in his thesis "*Vibration data coming from the painting frame, packing case or wall provide little information about the actual behaviour of the canvas"* [22]. While the most valuable data from vibration measurements come undoubtedly from the canvas itself, the vibrations recorded on the frame can reveal the magnitude of the shocks that are significantly higher than the magnitude of regular cyclic loading that causes fatigue, and they can further be used in future numerical simulations. They are also valuable for comparison should there be a benchmark.

Results and discussion

Shock Measurements

Although the total results of the shock experienced with the different trolleys are in general as expected as seen in table 1, the results also showed some irregular and unexpected results. Comparison between the small trolley with small wheels and the trolley with larger wheels without foam depicted in figure 3 shows that the larger wheels consistently reduce the amplitude of the shocks recorded on the trolley. As seen in figure 3, in some cases, the amplitude of the shocks for the small trolley with small wheels was close to 10g or higher. The highest levels of shocks were recorded at the thresholds although the trolleys were lifted while crossing these thresholds.

In order to investigate the effectiveness of the protective foam in reducing the shocks, the measurements were repeated with the large trolley with and without the foam. Unfortunately, as the results shown in figure 4 (right) demonstrate, due to the limitation of the measurement equipment, and the relatively low amplitude of the shocks for the large trolley, it is not possible to make an evaluation of the effectiveness of the protective foam. Furthermore, the measurements were also repeated for the small trolley with and without the foam but the results were again inconclusive mainly due to the human factors that impact the amplitudes of the shocks.

The difference between the large and small trolleys is however obvious as shown in figure 4. The measurements show huge differences between small and large trolleys passing the thresholds and bumps in the floor although both have the same wheels and the protective foam. While no shocks were recorded with the largest trolley with cushioning foam on platform, the shock levels on the small trolley in the same route reached 10g passing the highest threshold into the storage (Fig. 4). In this example of the small trolleys as demonstrated in figure 4, we also recorded 4 shocks beneath 4g in addition to those above 4g. The example shown in this figure is comparable to all the other monitored routes with small and large trolleys as summarized in Table 1. This may be caused by both the weight of the trolley in itself, and the fact that the art technicians did not lift the larger trolleys as high as the smaller trolleys, and they also lifted the large trolley smoother because of its greater weight.

Some of the shock levels recorded in these tests, especially for the small trolleys, are very high, even higher than earlier research has shown when crates are loaded into airplanes and in cargo halls [17]. It is not straightforward to compare these levels with earlier research, because the materials involved and the measurement methods used are different.

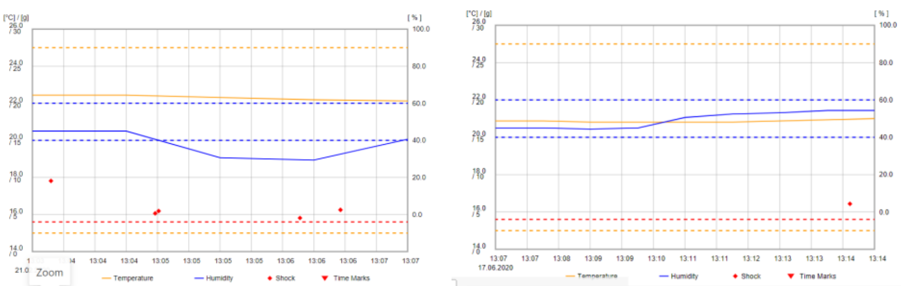

Fig. 3. Transfer from Photo studio to storage. Left: Small trolley, small wheels, no foam, from left in graph, threshold out of studio, into elevator, and out of elevator (two thresholds)

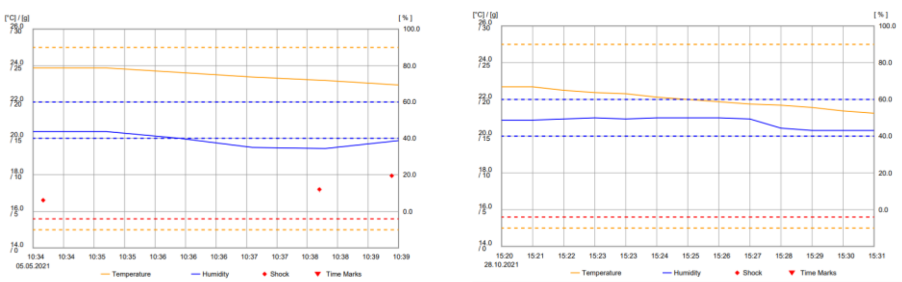

Fig. 4. These graps are from the same route: Conservation studio to storage. Left: Small trolley with foam, large wheels.Right: Large trolley with foam, large wheels

Vibration Measurements

The results of the acceleration measurements are presented separately for the small and large picture frames. The ID numbers given in Table 2 are used to indicate the routes in the figures, which correspond to the numbers given in color-coded squares. For example, the trips included in figure 5 are for the routes ID#1 to ID#4 as indicated by the color-coded squares. Note that only the accelerations in the vertical direction are presented as they represent the focus of this study. Figure 5 represents the maximum absolute accelerations recorded during the first ten trips, *i.e.*, for the small frame. It is observed that when the trolley was lifted (trips one and four), the max accelerations were much lower compared to those when the trolley was not lifted, especially for the route between the storage and exhibition. The highest accelerations were observed during Trip 6 while the trolley was traveling between the storage and the exhibition room, a route that had several thresholds at the entrance of the rooms as well as at the elevator.

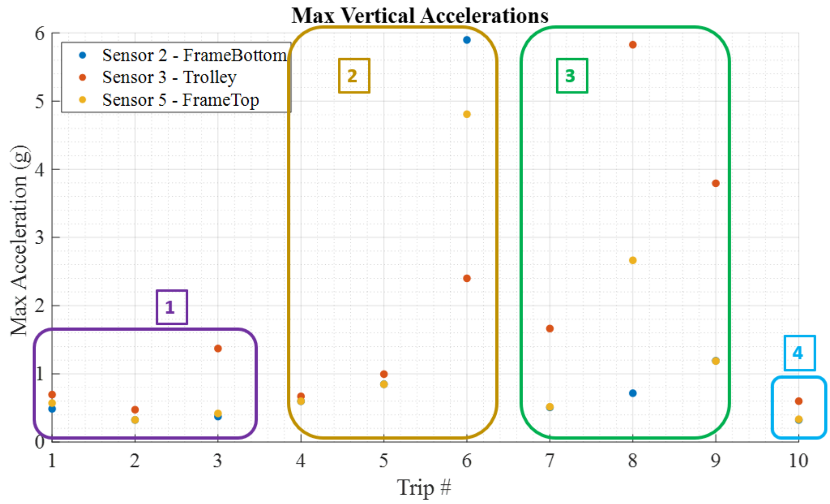

Fig. 5. Maximum values observed in the time-history of accelerations for the small frame

Figure 6 presents the variation of the acceleration with time on trip #6. The entire trip lasted approximately six minutes and, as can be seen from figure 6, the trolley traveled over several obstacles or rough surfaces, but the vibrations stayed below 1g, except an instantenous shock when the trolley was traversing one of the obstacles on the route where the acceleration levels reach 6g. Another observation from figures 5 and 6 is that, in general, for the small frame, the accelerations on the trolley were higher than those on the frame. However, for trip#6, the vibrations on the frame were higher than those recorded on the trolley.

To be able to understand why the accelerations on the trolley are consistently higher than those on the frame, the Fourier Amplitude Spectrum (FAS) of the vibrations recorded during trip #8, which produced the highest accelerations along with trip 6, is plotted in figure 6. The FAS of a vibration record indicates the frequency content of the vibrations (Fig. 7). Accordingly, the vibrations recorded on the trolley can be associated with higher vibration frequencies (above 25Hz) compared to the vibrations measured on the frames. This is most likely due to the way the frames were placed on the trolleys. More specifically, since the frames were placed on the trolleys without any rigid connection and mounting, they are less rigid compared to the trolley resulting in higher frequency vibrations on the trolley. Further, high-frequency vibrations are generally characterized by higher accelerations leading to the higher accelerations on the trolley compared to those measured on the frame.

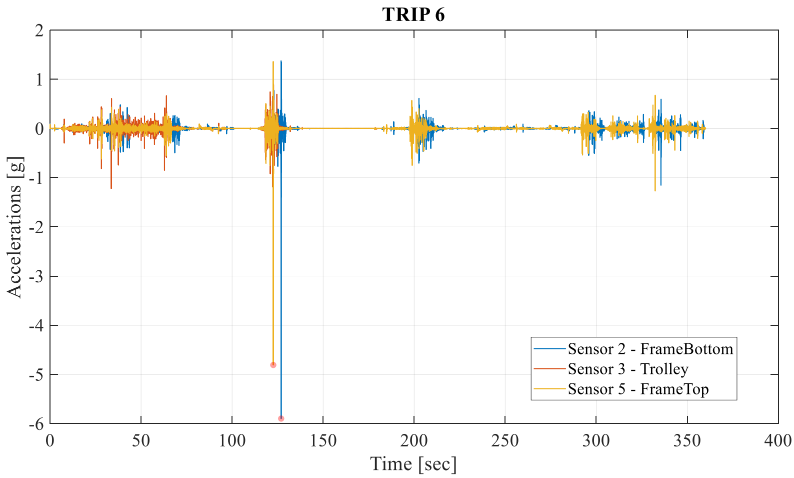

Fig. 6. Time-history of the vertical accelerations recorded during trip #6

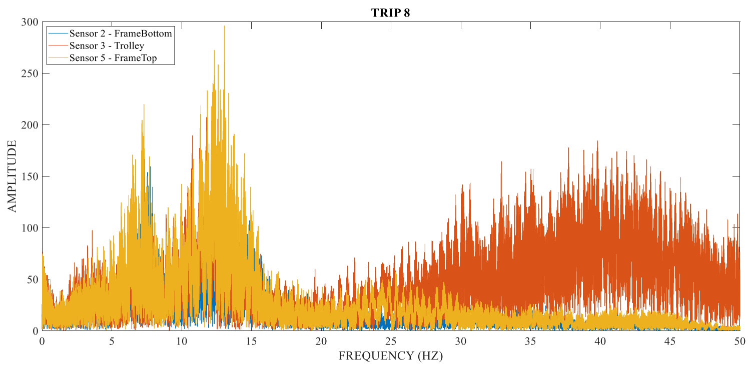

Fig. 7. Fourier amplitude spectra of the acceleration recordings during Trip 8

The absolute maximum vertical accelerations recorded for the large frame are presented in figure 8.

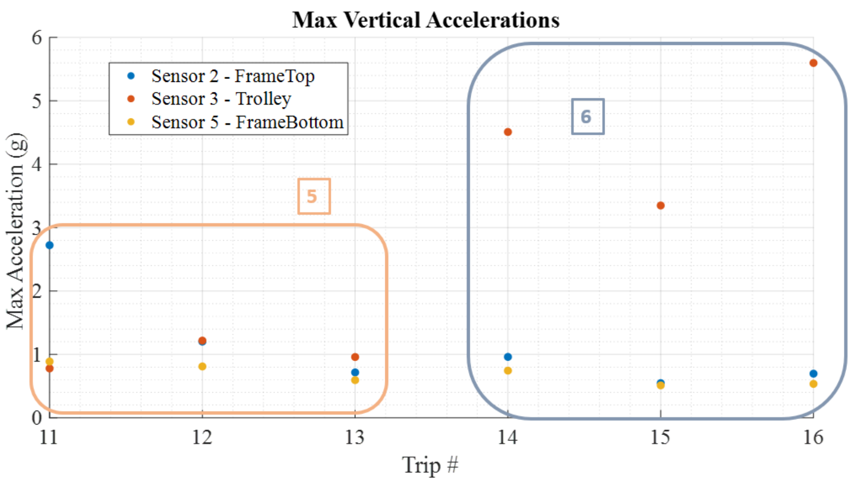

Fig. 8. Maximum values observed in the time-history of accelerations for the large frame

Notice that the trolley was not lifted during the trips for the large frame to account for the most unfavorable conditions. Again, route number six, which traveled between storage and exhibition, produced the highest accelerations. As in the case of the smaller frame, the accelerations on the trolley were consistently higher than on the frame during these trips. Furthermore, comparing the maximum accelerations recorded on the small and large frames (Figs. 6 and 7) show that those recorded on the large frame are consistently lower. This can be explained with the higher mass of the frame, which, when all other parameters are constant as in these experiments, leads to lower vibration frequencies and, hence, lower accelerations.

The overall results show that the route between storage and exhibition halls seems to be more prone to greater shocks. Lifting the trolley carefully at the bumps reduces the shocks, but this behavior cannot be guaranteed during the handling of the paintings by different art technicians. At least in some cases the accelerations on the trolley and the frame were very different. This is especially true for trip #16, *i.e.*, route six of the large frame, from storage to the exhibition. The accelerations measured directly on the trolley were above 3g for each of the three trips, with one approaching 6g. However, during the same trip, the maximum accelerations at the top of the frame were less than 1g. The measurements on the trolley may not be very indicative of what was happening to the frame and the painting.

By and large, the limits for the shocks and repeated accelerations of the paintings are unknown. A limit to ensure the paintings are not damaged could only be achieved by mapping the acceleration levels for various types of frames, trolleys, and paintings.

Concluding Remarks and Open Challenges

In this study, the results of an experimental campaign to measure the vibrations occurring on paintings during their in-house transportation are reported. The campaign was divided into two phases. In the first one only the amplitudes of the highest shocks during the transportation were measured, while in the second phase the entire vibration histories were recorded. The initial mapping shock measurements using Testo 184 1G indicate that the trolley size has a significant effect on the number and amplitude of the shocks experienced by the paintings. The larger the trolley, the lower and fewer shocks recorded. This is most likely due to the higher mass and lower stiffness of the larger trolley leading to a lower natural frequency, which further leads to lower acceleration amplitudes. In addition, large rubber wheels also reduced the shocks recorded owing to their damping characteristics. Thus, it can be stated that larger trolleys with large rubber wheels and covered with foam on the platform and on the trolley’s wall can be the best alternative in terms of reducting the shocks the paintings experience during their transportation.

The shock measurements were useful to map the main risk areas of the old Munch Museum during the transfer of the paintings but were limited in the information they provided as only the amplitude of the shocks could be recorded with the Testo 184 1G. To be able to understand the vibrations experienced by the paintings during their in-house transportation, the measurements were repeated using three tri-axial accelerometers that can record the entire time history of the vibrations at a sampling frequency of 500Hz. Analysis of the vibration data showed that the frequency content of the vibrations recorded on the trolley and frame varied, resulting in a significant discrepancy in the amplitude of the vibrations recorded at these two locations. As expected, the vibrations with the higher frequency content have higher amplitudes while the lower frequency motions recorded, e.g. on the larger frames, tend to have much lower amplitudes. As such, it can be concluded that the vibration on the trolley may not be indicative of the vibrations on the frame. Similarly, the vibrations measured on the frame may not be a clear indication of the vibrations on the canvas due to their different natural frequencies, indicating the need for more detailed measurements including the vibrations on the canvas. In the next phase of the collaboration project, vibrations on the canvas itself will be measured using low-mass accelerometers and strain gauges.

There are several open challenges on the topic of mechanical loads and their impacts on paintings. To be able to objectively evaluate the impact of vibrations on canvas paintings, a method to quantify their direct effect on the bonding forces needs to be developed. Most of the literature that studies the effect of vibrations on paintings so far focuses only on the amplitude of vibrations and the acceptable vibration levels are based on expert opinion without any experimental or theoretical basis. A new approach that objectively quantifies the reduction in bonding forces and loss of paint mass is urgently needed for more reliable and consistent evaluation of the effects of vibration on fragile canvas paintings. Finally, there are several other vibration sources that have the potential to adversely impact canvas paintings. These sources include, but are not limited to, vibrations due to traffic close by, footfall of the visitors and music played during the exhibition halls but also vibrations caused when the paintings are stored on moveable screens. Potential impacts of such vibration sources on canvas paintings remain largely unknown to date and need to be investigated in detail.

Acknowledgments

The authors are grateful to the art technicians Andreas Hans Mikael Öhman, Enrique Eduardo Roura Perez, Andrea Galiazzo and Tomas Siqveland Einarsson for transferring the trolleys during the measurements and making these measurements possible. We also acknowledge the collaboration with Barbara Ida de Haan and Kine Lillestrøm, former project leaders at MUNCH for the project *Moving MUNCH* to a new Museum, Ingvild Vestvik, former registrar at the same project. We also want to thank Mohammadreza Salehi at OsloMet who contributed to the measurements on the trolleys, and Mie Mustad, paintings conservator at MUNCH, for input and collaboration. A huge thanks to Clare Brignall for spelling and grammar check.

References

[1] C. Palmbach, N. Bäschlin, M. Läuchli, *Backing boards and glazing on paintings: Their damping capacity in relation of shock impact and vibration,* **ICOM-CC, 16th Triennial Conference**, Lisbon, 2011, pp. 19-23.

[2] J.P. Caldicott, *Vibration and shock in transit situations: A practical evaluation using random vibration techniques,* **Art in Transit – Studies in the Transport of Paintings: International Conference on the Packing and Transportation of Paintings, London, Sept. 9–11** (Editor: M.F. Mecklenburg), National Gallery of Art, Washington, 1991, pp 333-334.

[3] J.P. Marcon, *Shock, vibration and the shipping environment,* **Art in Transit – Studies in the Transport of Paintings: International Conference on the Packing and Transportation of Paintings, London, Sept. 9–11** (Editor: M.F. Mecklenburg), National Gallery of Art, Washington, 1991, pp. 121–132.

[4] D. Saunders, *Monitoring shock and vibration during the transportation of paintings,* **National Gallery Technical Bulletin, 19,** 1998, pp.64-73.

[5] Ł. Lasyk, M. Łukomsky, Ł. Bratasz, R. Kozłowski, *Vibration as a hazard during the transportation of canvas paintings,* **Conservation and Access: Contributions to the London Congress 15-19 September 2008** (Editors: D. Saunders, J.H. Townsend, S. Woodcock), The International Institute of Conservation of Historic and Artistic Works, London, 2008, pp. 64–68, Original publication is avaible at: http://www.iiconservation.or

[6] C. Palmbach, N. Bäschlin, M. Läuchli, *Backing boards and glazing on paintings: Their damping capacity in relation of shock impact and vibration,* **ICOM-CC, 16th Triennial Conference**, Lisbon, 2011, pp. 19-23.
[7] C. Palmbach, N. Bäschlin, M. Läuchli, T. Fankhauser, A. Hoess, (2013). *Transportmonitoring bei Gemäldetransporten – Neue Datensammlung zur Charakterisierung der Schock- und Vibrationsimmissionen,* **Tagung des Österreichischen Restauratorenverbandes 2012**. Konservieren, Restaurieren: Vol. 14, Österreichischer Restauratorenverband, Wien, 2013, pp. 30–41.
[8] M. Läuchli, C. Palmbach, N. Baschlin, *Packing systems for paintings: Damping capacity in relation to transport-induced shock and vibration,* **ICOM-CC, 17th Triennial Conference,** Melbourne, 2014.
[9] K. Kracht, T. Kletschkowki, *From art to engineering: A technical review on the problem of vibrating canvas, part I: Excitation and efforts of vibration reduction*, **Mechanical Engineering, 15**(1), 2017, pp. 163-182.
[10] W. Wei, L. Sauvage, J. Wølk, *Baseline limits for allowable vibrations for objects,* **ICOM-CC 17th Triennial Conference**, 2014, Melbourne.
[11] A. Gmach, *Erschütternde Umstände. Schwingungsbelastung von Kunst- und Bauwerken,* **Master Thesis**, Technical University of München, 2014.
[12] K. Kracht, T. Kletschkowki, From art to engineering: *A technical review on the problem of vibrating canvas, part I: Excitation and efforts of vibration reduction,* **Mechanical Engineering, 15**(1), 2017, pp. 163-182.
[13] D. Thickett, *Vibration damage levels for museum objects,* **ICOM-CC 13th Triennial Meeting**, Rio de Janiero, 22-27 Sep., 2002.
[14] W. Wei, L. Sauvage, J. Wølk, *Baseline limits for allowable vibrations for objects,* **ICOM-CC 17th Triennial Conference**, 2014, Melbourne.
[15] W.B. Wei, E. Dondorp, *Testing to determine allowable vibration limits at a natural history museum in the Netherlands,* **APT Bulletin: The Journal of Preservation Technology, 51**(4), Special Issue: Mitigating vibration damage, 2020, pp. 19–26.
[16] A.P Johnson, W. R. Hannen, *Vibration limits for historic building and art collections,* **APT Bulletin: The Journal of Preservation Technology, 46**(2/3), 2015, pp. 66–74.
[17] D. Saunders, *Monitoring shock and vibration during the transportation of paintings,* **National Gallery Technical Bulletin, 19,** 1998, pp. 64-73.
[18] P. G. Chiriboga, *Finite Element Modeling of Vibrations in Canvas Paintings***, PhD Thesis**, Universiteit Delft, 2013.
[19] K. Kracht, *The investigation of the vibration behavior of canvas dependent on weathering,* **PhD Thesis**, Technical University of Berlin, 2011.
[20] C. Palmbach, N. Bäschlin, M. Läuchli, *Backing boards and glazing on paintings: Their damping capacity in relation of shock impact and vibration,* **ICOM-CC, 16th Triennial Conference**, Lisbon, 2011, pp. 19-23.
[21] D. Rudenko, M. Sharif, B. Warner, *A Blueprint for managing construction-vibration risk at museum,* **APT Bulletin: The Journal of Preservation Technology, 51**(4), Special Issue: Mitigating vibration damage, 2020, pp. 37-44.
[22] P.G. Chiriboga, *Finite Element Modeling of Vibrations in Canvas Paintings,* **PhD Thesis,** Universiteit Delft, 2013.

Received: August 15, 2022
Accepted: December 17, 2022