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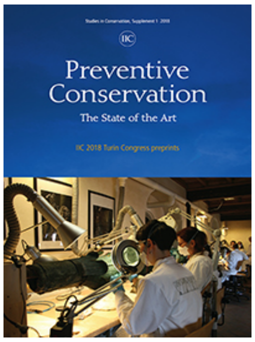

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POSTER

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When Conservation Meets Engineering: Predicting the Damaging Effects of Vibrations on Pastel Paintings

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Traveling exhibitions give the public the opportunity to see works of art which are otherwise in various collections scattered around the world. They require objects to be moved, exposing them to many risks including possible damage due to sudden changes in environmental conditions or in mechanical loading (shock and vibration). Vibrations have been identified as one of the most important risk factors during transport (Stolow 1967; Mecklenburg 1991).

Eighteenth-century pastel paintings are a group of objects often requested for loan because they are seen as examples of the heyday of the technique. However, they are also one of the most fragile types of artwork, because the medium adheres poorly to the support (Figure 1). Pastel paintings are made up of a complex set of powdery layers applied directly as a pastel stick to a support of paper or parchment. Some artists and on occasion conservators tried to protect pastels by spraying fixative at the surface, and more often, by keeping them behind glass. However, little data is available to predict what vibration conditions (strength and duration) are acceptable for pastel transportation (Esser 2011; Wei, Sauvage, and Wölk 2014). This paper discusses important initial results of a collaborative study begun in 2014 that aims at determining acceptable vibration conditions for the transport of pastels.

For this work, vibration testing was conducted on 30 mock-ups representative of eighteenth century pastel portraits. A technical survey of 95 pastels from the Rijksmuseum collection showed that such pastels were made on parchment or paper lined with canvas, with an average size of 50 × 40 cm. As it is difficult to obtain large quantities of parchment of consistent quality, this study focused on paper supports. A collaboration with papermakers resulted in the recreation of the inexpensive, non-sized and rough wrapping paper sheets used by pastellists at that date. The drawing pattern, made with Girault pastels, replicates the most important colors, and their distribution over the supports, for the Rijksmuseum collection. One set of mock-ups was made by hand to mimic pastellists' techniques. Another set was made with a scanner equipped with a spring-loaded pastel holder. The spring insured that the amount of pastel medium applied was the same for all mock-ups, by applying the same force using the same scanning pattern. Three mock-ups were fixed by spraying two layers of synthetic resin-based 'Pencils and Charcoal – Delacroix' fixative (Sennelier).

Vibration testing was conducted by mounting the mock-ups on a biaxial stretcher, which can apply loads typical of those for historical pastel paintings stretched on strainers (Figure 2). These loads are based on eighteenth century treatises such as De Chaperon (1788, 330) who described the procedures for stretching pastel supports. Pastellists humidified the paper and allowed it to expand before glueing its four edges onto a strainer. As a hygroscopic material, the paper would then dry and stretch flat without the application of external forces. Strain-controlled tests performed by the authors on handmade paper strips showed that the stress upon drying reaches equilibrium at approximately 4 N/mm^2, in both grain and cross directions. 55 × 65 cm paper sheets (A) were clamped on four sides with aluminum profile lined with rubber (B). Each clamp was mounted with bolts inside the aluminum profile and connected to the biaxial stretcher (C) with drive screws (D). By turning the drive screws, it was possible to stress the paper gradually up to 4 N/mm^2. Load cells (E) installed in the two stretching directions measured the tensile load applied and ensured that the stress was the same for all of the mock-ups.

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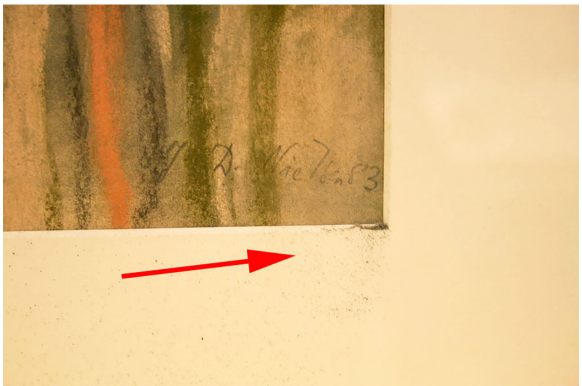

Figure 1. Detail of a framed pastel showing pastel loss after transport.

Each mock-up was tested at a given vibration amplitude, using a pure sinusoidal signal produced by a function generator (TOE 7741, Toellner) and applied to the mock-ups using a subwoofer (IPS 18E-R, BagEnd) (F) positioned under the mock-up (A). The fatigue tests were stopped when either failure or unacceptable damage level had been reached, and the corresponding number of cycles was recorded. This failure level was defined as 1% of surface change, based on the results of perception tests conducted with conservators, curators and art handlers.

The results are plotted in the form of S-N (Wöhler) type diagrams, which relate stress amplitude S to the number of cycles N (duration) to failure (Figure 3). In this study, the vertical axis stress amplitude was replaced by displacement amplitude. In Figure 3, the solid data points indicate mock-ups that reached failure. Six specimens, indicated by an arrow, did not fail within the duration of the test (two to four days).

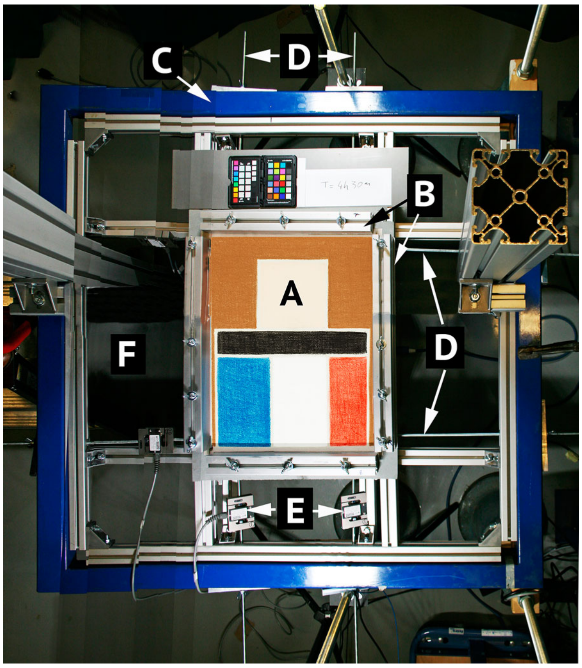

Figure 2. Biaxial vibration setup at the Delft Technical University. (A) mock-up; (B) clamp; (C) frame; (D) drive screw; (E) load cell; (F) vibration source (under mock-up).

Pastel paintings are particularly susceptible to medium loss since they are only held by the mechanical interaction between rough agglomerates and paper surfaces. The question posed for such works is whether loss of medium is a cumulative effect from repeated application of low-amplitude stresses or whether pastel agglomerates would fall off if any cyclic stress simply exceeds the strength of the medium/paper bond.

The results presented in Figure 3 show that the mock-ups do not fail immediately, but that damage occurs after a certain number of cycles, depending on the amplitude level they experience and the properties of the mock-ups. A Student t-test conducted on the results showed that at lower displacement amplitudes, the fatigue life of the specimens appears to be significantly longer ($M = 1.8.10^6$ cycles, $SE = 1.8.10^6$) than at higher displacement amplitudes ($M = 2.8.10^5$ cycles, $SE = 3.8.10^5$), for $t(22) = 3.19$, $p < 0.05$. Furthermore, three specimens did not fail within two days of continuous testing (almost 10^7 cycles), indicating a possible approach to an endurance limit for unaged and unfixed pastels on paper. A second trend is that three specimens, coated with a fixative and tested at 4.3 mm displacement amplitude clearly had a longer life than their unfixed counterparts, which did not fail after four days of continuous vibration testing.

All of the 'failed' mock-ups showed a transfer of black agglomerates onto the pink area, in the middle of the sheets. This could be explained by the fact that the mock-ups were excited in mode 1, which means that the center of the sheet experienced the highest displacement amplitude and the interface between medium and paper at this location was subjected locally to higher stress than the other areas. However, preliminary tests involving replacement of the black medium by pink showed that, under the same loading conditions, pink agglomerates did not move, indicating an influence of the pastel morphology or composition on the adhesion of the medium to the paper. SEM imaging of the medium showed that the black medium contains large particles (1–20 μm) and very small round grains (60 nm), while needle-shaped particles are present in the pink medium. The large black grains are not as well embedded in the paper fibers as the pink agglomerates, and are more likely to lose adhesion at the higher stress amplitude level at the center of the paper.

Further, freshly made mock-ups with a fixative did not fail after four days of testing, showing a possible improvement of the fatigue life due to the presence of a fixative. The unaged synthetic fixative seems to act as a coating providing extra chemical and mechanical support to 'fix' the pastel agglomerates to the

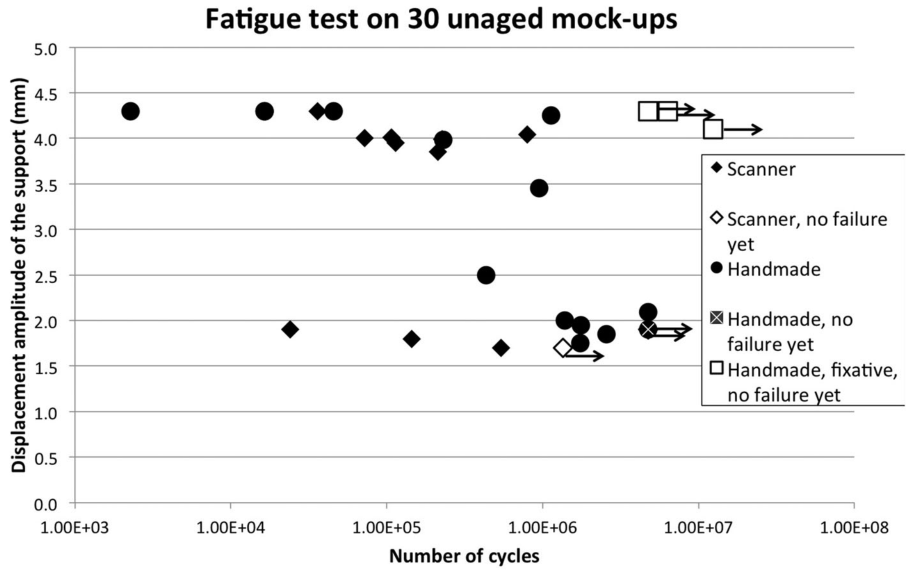

Figure 3. S-N type diagrams (displacement amplitude *vs*. number of cycles) for unaged pastels with and without fixative. The arrows indicate specimens that had not failed when the test was terminated.

paper support. It should be noted that this does not imply that one should use a fixative to protect pastel paintings from vibrations. It gives a first indication that pastels that have been fixed may be less fragile than those without fixative.

The results of this project thus far show that damage in pastel paintings due to vibrations is cumulative, and appears to show Wöhler type behavior, with a longer expected lifetime at lower displacement amplitudes. Further testing will be conducted to expand the fatigue database, and to investigate the effect of other parameters, such as fixatives, aging, surface roughness and pastel painting methods. These results can be used to analyze vibration measurements taken during transport. It should be noted that real transport vibrations consist of a range of amplitudes, so that one would have to apply the concepts of the so-called Palmgren-Miner rule (see e.g. Hertzberg 1996) and rainflow counting algorithms known in, among others, the aircraft industry. These two concepts would allow conservators to determine what percentage of the 'lifetime' of a pastel has been spent during the trip at each vibration level shown in the Wöhler diagram, Figure 3. With this information, they could predict how much life it still has, that is, how many more trips, if any, it could undertake before damage becomes unacceptable. At the moment, there is little data on vibrations during the transport of pastels. However, the authors have recently made a number of measurements, but these first need to be analyzed using the algorithms just mentioned.

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