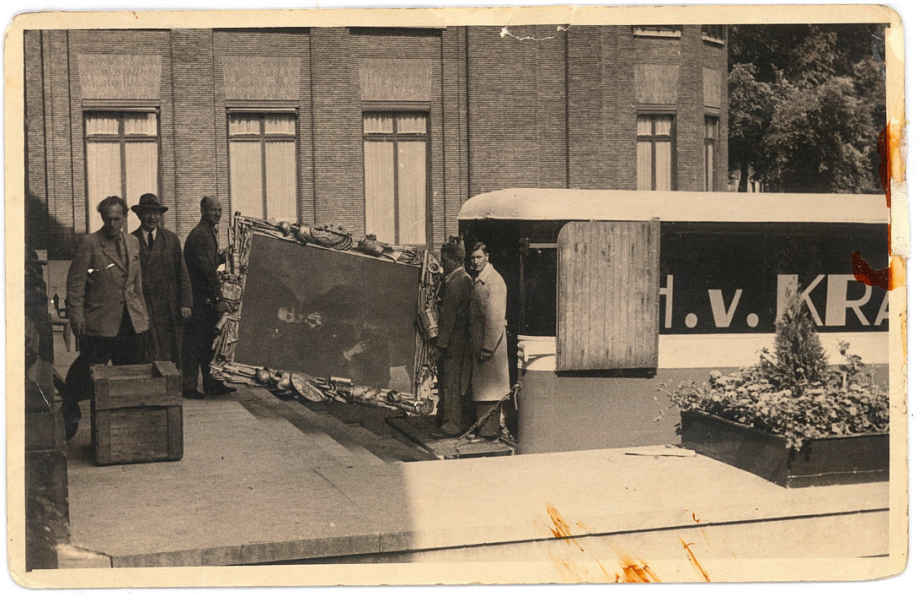
TRANSLATED VERSION OF THE ORGINAL ARTICLE PUBLISHED IN RESTAURO NR. 7 2018



1. Transport of the painting "Portrait of Michiel de Ruyter" (1667) by Ferdinand Bol, in 1950, from The Mauritshuis in Den Haag to the storage depot due to building works in the museum.

TURTLE® UNLTD

The safe transport of works of art and cultural artefacts

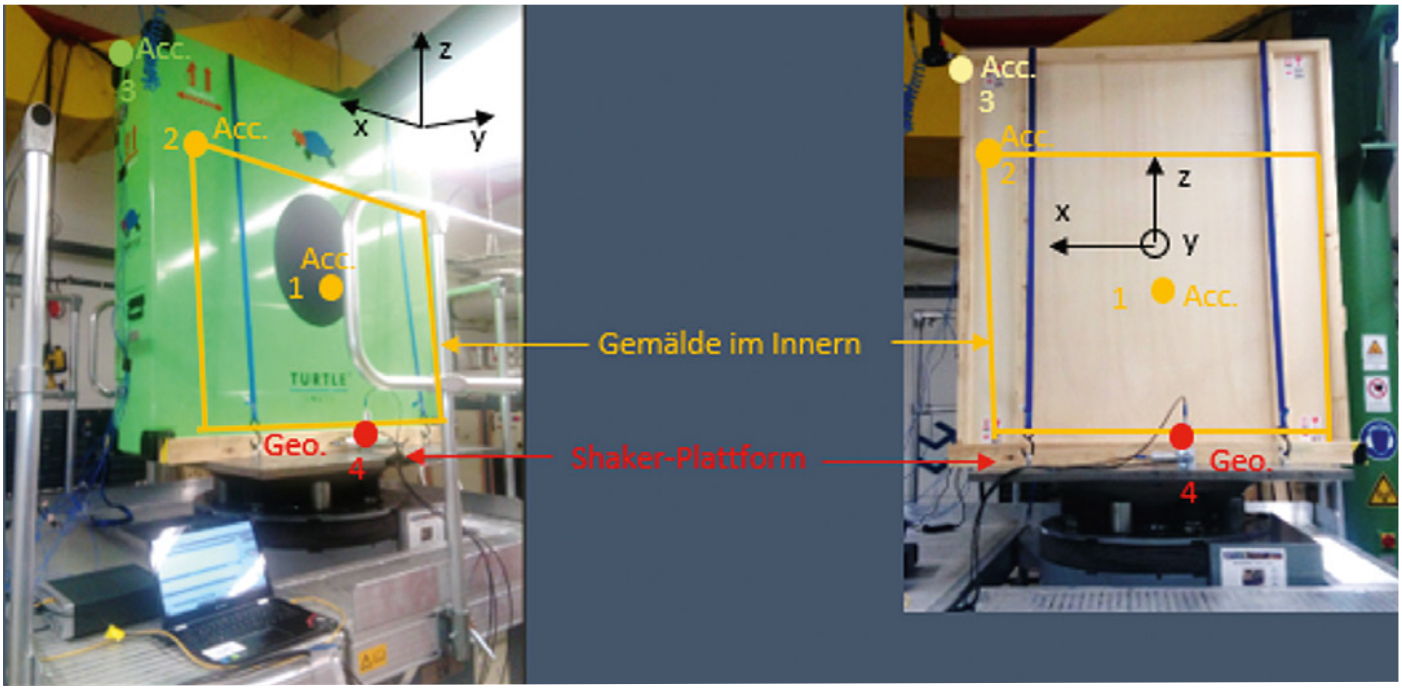
As recently as 100 years ago works of art were transported on the back of a horse-drawn cart. Shortly afterward, furniture removal firms took over this work. Today, however, it is done by highly specialized companies who even submit their transport crates to physico-dynamic analysis before using them to move paintings. A test report.

The problem of how to transport works of art and other cultural artefacts is one which has preoccupied for centuries artists, art-collectors, curators and many others interested in art. It is not by chance that, above all since the Renaissance of the 15th and 16th Centuries, painting has been executed mostly on flexible materials such as textiles. A rolled-up canvas, after all, is much easier to transport than a wooden panel, especially if the painting executed on it is of a larger size.

Qualified conservator Thomas Hoppe, who, apart from working as a painting restorer, was also himself an artist and the author of many writings on painting techniques, once said: "Art is something to be seen". But ever since the foundation of the first German museums in the 17th Century, "being seen" has, due to renovations, reconstructions and extensions to these institutions as well as to touring exhibitions and special shows, more and more often involved "being transported". This trend is still growing today. But how does the transport of artworks today differ from that in the past?

As recently as 100 years ago it was usual to transport artworks, wrapped in blankets, on the back of a horse-cart or on the back seat of an early automobile. A little later, furniture removal firms took over the transportation of these fragile goods. One of these firms was H. v. Kralingen, founded in 1926 in Den Haag in the Netherlands. This photo from 1950 shows the transport of the painting "Portrait of Michiel de Ruyter" (1667) by Ferdinand Bol. The moving of this work was made necessary by the renovations carried out in the Mauritshuis Museum in this city, which went on for two years.

Since this time, transport methods have been in constant evolution. The transport trucks are now air-conditioned and air-sprung; the blankets were replaced first by wooden crates and more recently by re-usable climatized containers made of high-tech compound materials. There now even exist two German and European "product standards" specifically regulating "The Preservation During Transport of Objects Belonging to the Cultural

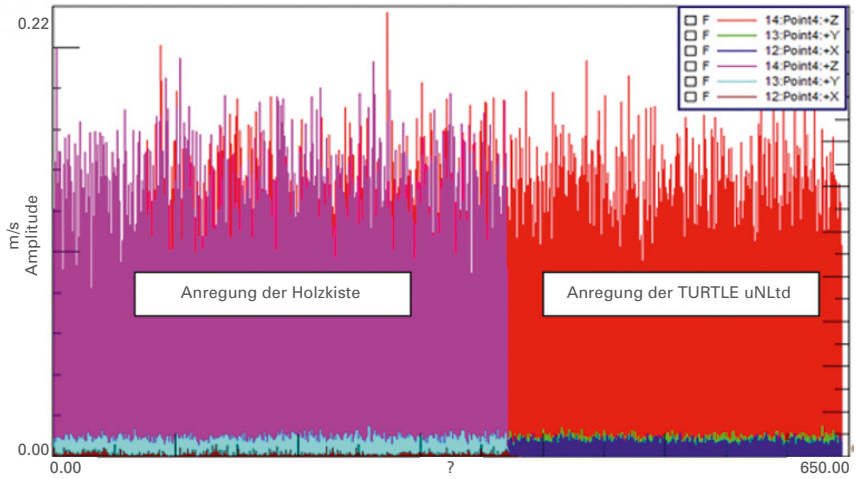


2. Test set-up during transport simulations for the painting-transport crate TURTLE uNLtd (left) and for a conventional wooden climatic transport crate (right) in accordance with the stipulations of Guideline ASTM D4728-15

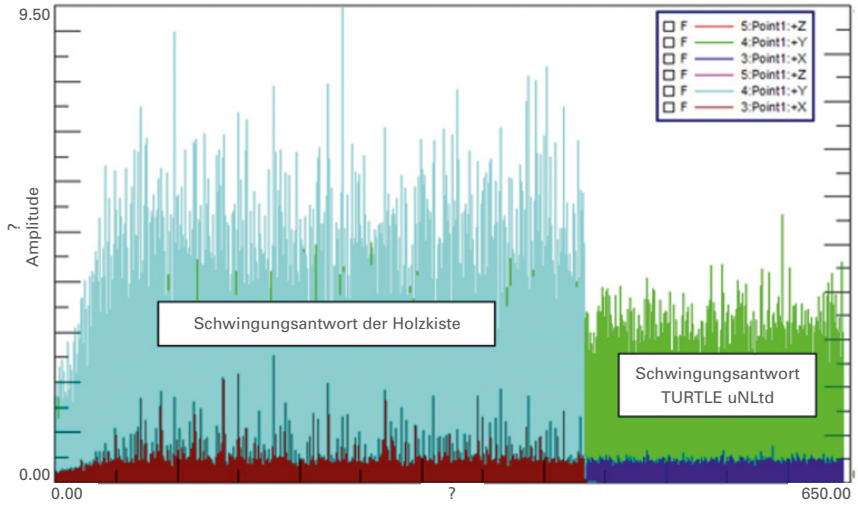
Heritage: Ideally, a transport crate for an artwork should guarantee, in its interior, environmental conditions identical to those in a museum, even when external influences are at their harshest. The relevant negative external influences likely to be met with in a museum are summed up in a list entitled "Ten Agents of Deterioration". The transport crate itself should offer especial protection against climatic fluctuations, sudden impacts and vibrations. The other "agents of deterioration" – such as fire, theft, flood etc. – should be excluded by means of securing procedures carried out prior or parallel to the crating.

How effective the crate is against climatic fluctuations, impacts and vibrations can be tested in environment labs. Product standards and guidelines prescribe the stress tolerances in these regards. Super-sensitive sensors are used to monitor the crates' reactions to fluctuations in environmental conditions. The guideline ASTM 4169 ("Standard Practice for Performance Testing of Shipping Containers and Systems") defines the basis for all packing tests.

As is shown, for example, very impressively in the film Das Atmen der Bilder ("The Breathing of Paintings") by Volker Schaible, climatic fluctuations and the stress and strain that they impose on the materials of artworks are so slight as to verge on being static. Nevertheless, very powerful forces come into play with even the slightest fluctuation. Were this not the case, we would not see flaking of paint occurring even at a relative atmospheric humidity of <50 %. It is correspondingly important, then, to ensure stable climatic conditions during the entire process of transport. The climatic stability of the transport crate should be tested before its use. The topic of climatic tests is specifically addressed in the product standard DIN EN ISO 2233: 2001 and the guideline ASTM D4332. Normally the crates and other packaging undergo a standardized pre-conditioning process to prepare them for the climatic tests. They are introduced into climatic test chambers which induce variations in both temperature and atmospheric humidity. Temperature and humidity gauges placed at various points inside the crate are used to observe any changes brought about by these variations. From the data thus gathered it can be inferred how long climatic conditions will stay stable in the crate during transport.

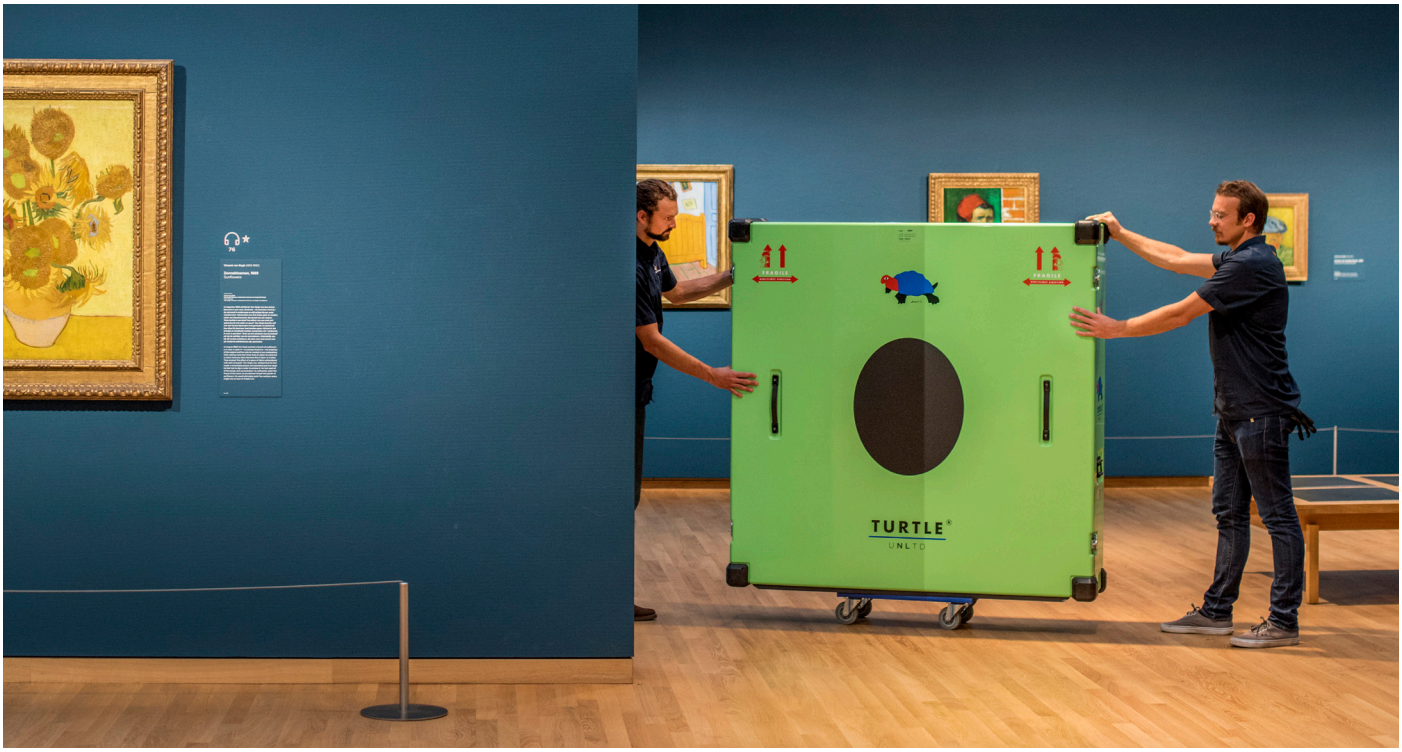


3. Peak values for the stimulus-signals (left) and for the vibration-responses emanating from the middle point of the painting (right) during the transport simulation. Where the stimulus is equal, the painting vibrates, when packed inside a TURTLE uNLtd, at only half the vibrational amplitude as occurs when it is packed in a normal wooden climatic crate.



4. Peak values for the stimulus-signals (left) and for the vibration-responses emanating from the middle point of the painting (right) during the transport simulation. Where the stimulus is equal, the painting vibrates, when packed inside a TURTLE uNLtd, at only half the vibrational amplitude as occurs when it is packed in a normal wooden climatic crate.

5. Set-up of measuring systems in the transport truck during real transport situations in the city, across country and on the motorway.

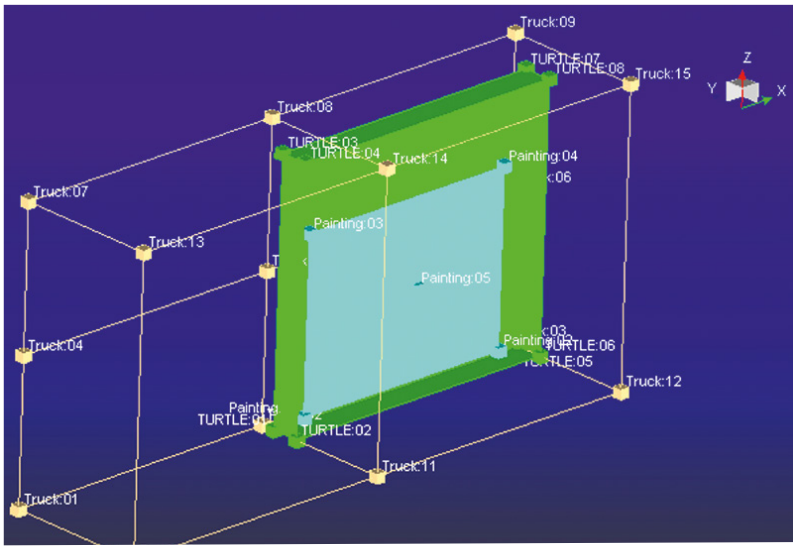


Although climatic stability is a very important concern it is often not an easy matter, on the German market for such techniques, to get information on the specific products available. In certain articles, such as Kunst auf Reisen ("The Travels of Art") by Eve Begov and Lutz Kuschel (RESTAURO 4/2007), artwork-restorers have presented the results of their investigations of the climatic stability of the typical transport crate. Clearly, in conventional climatic crates climatic conditions will remain constant and stable for the duration of a single day. This is also currently the standard guarantee, which coincides with the general specifications of German manufacturers of such products.

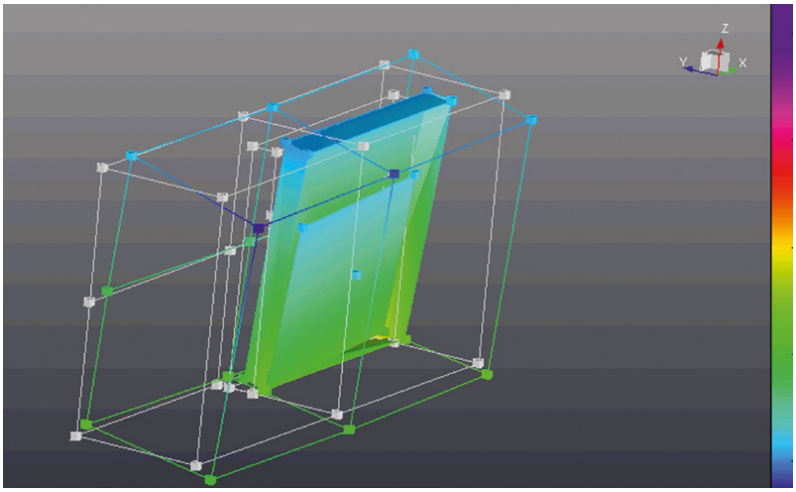
In a 2016 test report from the TOPA Institute in Voorhout in the Netherlands, however, the TURTLE uNLtd transport crate was investigated. This newly-developed product made from compound materials, it emerged, is able to maintain the climatic conditions within the crate at constant levels for a duration of more than two days.
Further progress, moreover, also needs to be made as regards the securing of transported artworks against such dynamic and mechanical strains and stresses as vibrations and sudden impacts. But before steps can be taken to achieve this further progress, the current state of affairs must be investigated.

This is certainly the view of Hizkia van Kralingen, grandson of the furniture-removal entrepreneur H. v. Kralingen, who is now himself active worldwide, from his base in Den Haag, as a transporter of artworks and cultural artefacts. In accordance with this view of things Hizkia van Kralingen has had two different painting-transport crates in use in his transport company investigated and tested by the independent vibration-stress expert "Dr. Kracht Vibrationsmanagement". These two transport crates were, on the one hand, a conventional wooden climate crate and, on the other, the TURTLE uNLtd painting-transport crate made of high-tech compound materials.
For the investigation of the crates' safety, during transport, from harmful influences of a mechanical nature, a transport simulation complying with the guideline ASTM D4728-15 was carried out. This involved lashing both crates, one after the other, to an electrodynamic vibration-generator (or "shaker") by means of lashing straps. The same painting was placed in each crate, one after the other and in the same position. The "shaker" was then set in operation in such a way that the crates were subjected, each in turn, to the vibrations and sudden impacts typically arising during road-travel on the loading-bed of a truck with air-sprung suspension. During the transport simulations the vibrations were measured at the following four points: middle point of the test painting (oil on canvas, 8.7 kg, (1.2 m x 0.9 m x 0.08 m) (1), corner of the test painting (2), corner of the crate (3), and mounting plate of the "shaker" (4).

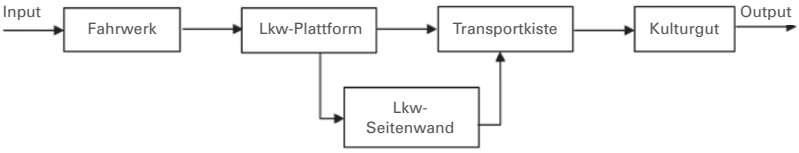
The measured results clearly show that, where the stimulus remains equal, the middle point of the canvas of the painting vibrates, when it is packed inside the TURTLE-Box, with only 50 % of the vibrational amplitude which occurs when it is packed inside the conventional wooden crate.



6. Measuring points for the investigation of the vibrational behaviour of the TURTLE uNLtd attached within the loading space of the truck together with the test painting packed into it.



7. Peak values for the stimulus-signals (left) and for the vibration-responses emanating from the middle point of the painting (right) during the transport simulation. Where the stimulus is equal, the painting vibrates, when packed inside a TURTLE uNLtd, at only half the vibrational amplitude as occurs when it is packed in a normal wooden climatic crate.



8. Transfer path of vibrations through the truck to the cultural artefact.

How closely, however, do the artificially-induced vibrations to which the crates are subjected during the transport simulations correspond to reality? For the purpose of assessing this, measurements were also carried out during real transport situations in the city, across country and on the motorway, specifically at the following three points: on the loading surface of a small truck, at one corner of the TURTLE-Box, and at the middle point of the canvas of the painting that had been packed into the crate.

The comparison between the data yielded by the measurements taken on the mounting plate of the "shaker" with those taken on the truck platform during the cross-country drive shows an extremely good concordance, at least in a vertical direction, between the peak values measured in the simulated and those measured in the real situation. Differences, however, exist as regards values measured in transversal and longitudinal directions. In these latter directions the peak values measured during the real transport situation were, on average, of an equal

amplitude but in certain situations 35 % greater. The proportion of vibrations occurring in a vertical direction, though, make up more than 80 % of the total, so that the differences noted as regards longitudinal and transversal directions are almost negligible. It is, however, important to know just where these differences came from. Information about this is provided by an analysis of the vibrational behaviour of the crate along with the test-painting attached within the loading-space of the truck.

The analysis of the different forms of vibration clearly shows that the deviations in vibration-amplitude that were measured during the real transport situation as occurring in longitudinal and transversal direction resulted from the vibrations of the truck itself ("natural vibrations" of truck). The relevant videos can be viewed at www.restauro.de.

From this insight, and from the observation of the specific transfer path of the vibrations, it follows that any further development of transport procedures must take into account the "natural" or "characteristic" dynamics of the means of transport itself.

But why, in fact, does a painting packed inside a TURTLE crate vibrate only half so much as one packed inside a wooden climatic crate? Information about this is provided by the experimental modal analysis using approx. 170 measuring points on both cases.

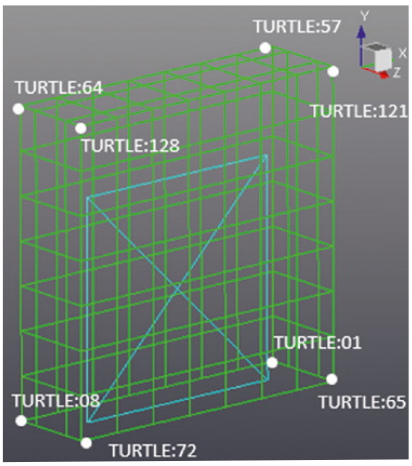
The experimental modal analysis uses measuring technology to determine the natural frequencies and natural vibration-forms as well as the degree of attenuation.

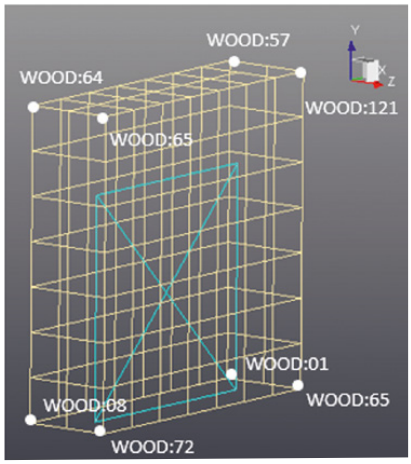
From the natural vibration-forms there can be derived transfer-factors and these transfer-factors indicate to what extent the forces to which the crate is exposed become, on their path through the crate to the painting, either attenuated or intensified. The transfer-factors are dependent on frequency. The largest transfer-factor experimentally established for the TURTLE uNLtd was 0.03 g/N and the largest one established for the wooden climatic crate was 0.06 g/N. It plainly follows logically from this experimentally established datum that the amplitude of the vibrations undergone, during the transport simulation, by the painting in the TURTLE crate will indeed be only half of the amplitude of those undergone by the painting in the wooden crate.

The reasons for the TURTLE crate's offering lower transfer-factors and thus better preserving the painting from vibrations during transport lie in the structure of the crate and the materials used to make it. These latter lead to a greater degree of rigidity than is found in the wooden crate and thus to an augmented attenuation. The greater weight of the TURTLE crate also contributes significantly to the vibration-reduction.

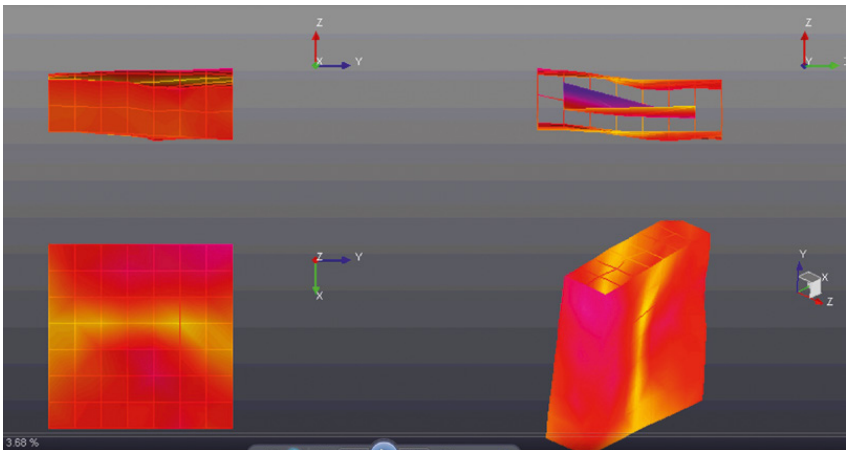
Other measurements examined the vibrations and impacts suffered by the crates during opening and closing. The comparison of the results measured here confirms what restorers have long supposed to be the case: the operation of the butterfly locks on the TURTLE

9. - 10. Measuring points on the TURTLE uNLtd and on the wooden climatic crate for the experimental modal analysis.

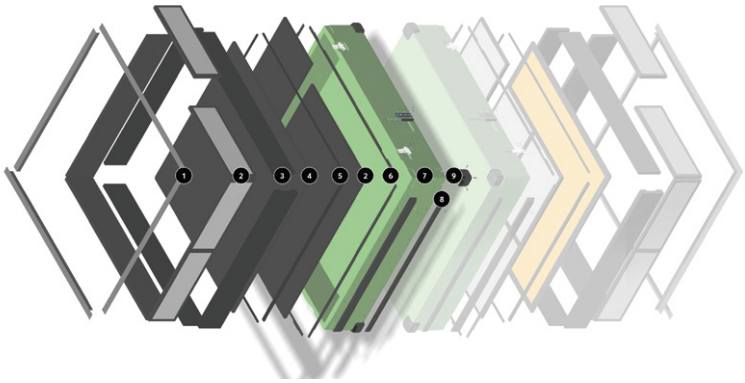




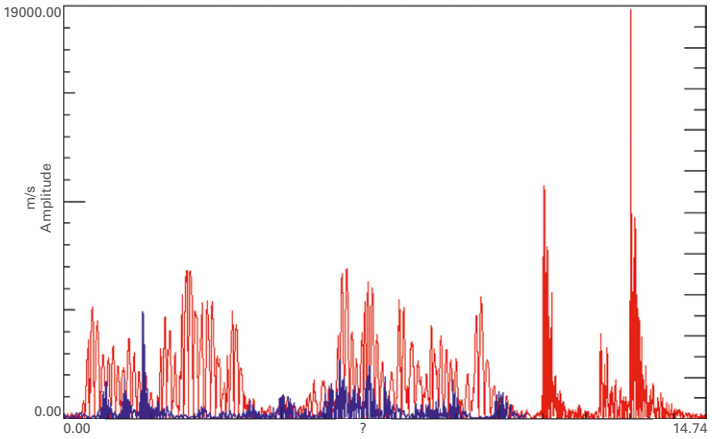
11. - 12. Measurement model for the two crates in the measurement software.



13. Natural ("characteristic") vibration of the TURTLE uNLtd, packed with test-painting, at a vibration of 24 Hz.



14. Construction of the painting transport crate TURTLE uNLtd: 1. Plastic angle section to protect the foam in the crate interior, 2. Insulating panels, 3. Interior foam: polyurethane foam and Plastazote, 4. Plywood panel made of birchwood coated with Velcro, 5. Foam encasing the plywood panels, 6. Insulating corner brackets, 7. Crate made from high-tech compound materials with foam core, 8. Nylon-HMPE sliding bolt, 9. Protective rubber corner-pieces.



15. Vibrations of the canvas in vertical direction during cross-country transport (red) and during fastening of screws with cordless screwdriver (blue).

a.) Transport Methods (DIN EN 16648:2015-11) und **b.)** Packing Procedures for Transport (DIN EN 15946:2011-11). These product standards, indeed, leave many questions open, particularly those relative to impacts and vibrations. Even certain talks on the subject delivered very recently, such as that given at the symposium Alles schwingt ("It's all about vibrations") in the Mannheim Kunsthalle on 30th of June 2018, recognize that more work needs to be done here.

crate occasions no relevant reactions from the test-painting but significant vibrations are caused by the screwing-closed of the wooden crates with a cordless screwdriver. The amplitude of the shocks created by the use of the cordless screwdriver amounts to 10 % of that of the shocks arising during the cross-country drive.

The latest investigations into the vibration-technical qualities of two currently utilized painting transport crates thus show visible progress in the safe transport of artworks and cultural artefacts. The analyses confirm that not only does the latest development on the market, the TURTLE uNLtd, "save the lives" of 40 trees per wooden crate (see "This Crate Saves the Lives of Forty Trees" in RESTAURO 7/2017); the vibrations undergone by a painting packed inside a TURTLE uNLtd amount to only 50 % of those undergone by the same painting when packed inside a wooden climatic crate. Moreover, the TURTLE uNLtd maintains climatic conditions in its interior constant for 48 hours. The TURTLE uNLtd thus sets the current standard for the physico-dynamic performance of painting transport crates.

Kerstin Kracht

Relevant videos are to be found at **www.restauro.de**

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