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Title

Monitoring panel paintings: two case studies

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Abstract

This paper concerns the study of mechanical behaviour after remedial conservation treatment during relative humidity variations of two European wooden panel paintings, of early 16th century, both conserved at the Fabre Museum, in Montpellier. One panel's treatment was carried out by conservators, based on their knowledge and empirical observations while the other one was accompanied by a multidisciplinary team, specialized on wood material and mechanical engineering.

Based on regular thorough condition reports and on data collected throughout long-term monitoring on the two paintings, both remedial treatments seem efficient and ensure satisfying conservation of their wooden support and paint layer.

Key words

panel painting, cradle, climate variation, stereo correlation monitoring, mechanical behavior

Introduction

The aim of the presented work is to define what happens to a panel painting in case of climate change, to calculate the range of tolerance to environmental variations and estimate the time needed to readapt to climatic norms as defined by ICOM. This could lead to a re-evaluation of the climate control in the Fabre Museum in response to the universal need to reduce energy consumption in museums.

We wish to evaluate the time of reaching stability, giving the possibility to fragile panels to better resist to climatic variations without submitting them to damage. Hopefully, this project studying the mechanical behavior of painted panels during climatic changes will initiate further reflection on how to better understand the influence of environmental conditions on the behavior of this type of paintings, improving decision making for the artworks treatment.

Over the years, various methods of remedial conservation have been used to conserve wooden panel paintings. In the two case studies presented here, the wooden supports had been restored in a comparable and rather interventionist manner in the past, with the result that the long-term conservation of the artworks was compromised.

By the beginning of 2010, each of the two panels examined had several cracks. Their paint layer suffered from losses as well as progressive deterioration, partly due to the constant cracking and locked-in strains of their wooden supports. These facts led the Fabre Museum to undertake new remedial conservation treatments. The aim was to better understand their condition and to apply the most appropriate solutions in order to conserve the two works of art in the best possible way.

For one of the two panels an innovative research was carried out before, during and after its remedial conservation (Bousvarou and al. 2020a; Jullien and al. 2023; Nicolas 2019). Conservation decisions were taken on the basis of data collected during six years of continuous stereo-correlation image monitoring, combined with other complementary analyses (Dupré and al. 2020) within the permanent exhibition rooms of the Fabre museum (Bousvarou and Stépanoff 2018, 2020b). For the other panel painting, monitoring was carried out only after its treatment in order to verify its mechanical behavior.

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Both remedial conservation treatments of the wooden supports were carried out by the same conservators.

2. Identification of the study cases

Panel N°1: *The life of Holy Agnes* (1519, Germany) (Figure 1)

Oil on lime tree

Unframed dimensions: Height 97 cm; Width 78 cm; Thickness 0,8 cm

Weight: 7,206 kg panel with a resin cradle with sliding screws -system

Remedial conservation between 2011 and 2013

Monitoring in 2017, in 2021-2022 and since July 2023

Panel N° 2: *The Holy Trinity Crowning the Virgin* (early 16th century, Flemish or Spanish) (Figure 2)

Oil on oak

Unframed dimensions: Height 113,7 cm; Width 97,8 cm; Thickness 0,48 cm

Weight: 15 kg panel with a resin cradle with self-tensioning spring system on sliding screws -system.

Remedial conservation between 2017 and 2022

Monitoring between September 2016 and July 2023

2.1 Comparison of condition report before remedial conservation

It is important to note that each of the two wooden panels is unique, as is usually the case with works of art. However, some structural comparisons can be made.

The two panel paintings appear to be quite similar in terms of their original technique and the methodology of previous conservation treatments observed. Another point of similarity would be the cause of their deterioration, as well as the similar methodology of recent remedial conservation. The main difference lies in the protocol used for the manufacture of the new cradle, in order to control any mechanical disturbance in the behavior of the wooden support.

2.1.1 Similarities

In both artworks the technique of the paint layer is oil paint with thick stripes on thin layers of oil paint. The preparation is white gesso and protein binder, not very thick, and gold leaf covers about 20% of the surface.

Both wooden supports are made up of several separate planks joined together with glue, missing wooden dowels and a fixed cradle at the back that doesn't appear to be original. The panels had been considerably thinned at some unknown time in the past, certainly during conservation treatment. The panels had many cracks, resulting in deterioration of the paint layer, which in both panels suffered from losses along the cracks and progressive tenting in large areas.

The main similarity between these two paintings is that they are now in very good condition, apparently stable within the current environmental conditions that correspond to the climate recommendations for museums (20°C +/- 5%, 50% RH +/- 5%).

2.1.2 Differences

The Life of Holy Agnes (panel N° 1), is about 10% smaller than the *Holy Trinity Crowning the Virgin* (panel N° 2). It is made up of three planks of lime, partly tangentially cut, with the presence of nodules and several xylophagous insect holes. The condition report notes six linear meters of cracks in the wood, some of which are very complex.

The thickness of the panel is 8 mm, due to thinning in the past, making it thicker than panel N°2. The surface is slightly convex and, as the conservators noted at the time of treatment, "*very sensitive to changes in humidity due to its partial tangential cut*". The back was reinforced at some unknown time

with an 18 mm thick cradle of unspecified softwood. It consisted of three uprights and five crosspieces glued together. As described by the conservators in their 2011 report, "*This extremely cramped frame has led to the partial splitting of the two joints and to the numerous cracks present on each board*".

The Holy Trinity Crowning the Virgin (panel N° 2) is made of four vertical oak planks. Three of them are quarter sawn (radial grain) and the fourth is flat sawn (tangential grain). The painting was cut on three of its four sides at an unknown time, which means that it came from a larger composition. Historical research into its provenance is still underway. The wooden support, slightly thicker than panel N°1, has been thinned to 10 mm. Fifteen line cracks were counted in the upper and lower areas. At the back of the panel, probably at the same time as the thinning, a complex auxiliary cradle of coniferous wood (*Abies* spp. (fir)) was added. It consisted of seven horizontal crossbars of 35 mm (width) by 15 mm (thickness) section made of fir (*Abies* sp.) glued onto the original oak planks. The entire surface of the back was covered with a layer of brown paint. The surface showed a 15 mm concave deformation between the upper and lower edges, but no insect galleries were observed.

2.2 Comparison of recent remedial conservation steps

The painted layer of the two artworks was restored by two different teams but the proposal was identical and involved consolidation, then deep cleaning of the original paint layer and finally restoration of the areas of loss. Finally, natural resin varnish was applied to the painted surface.

For the wooden supports of the two paintings, the proposal for remedial conservation, as fundamental as that for the paint layer, was similar and seemed appropriate in terms of art conservation standards. The two remedial treatments were operated by the same restoration workshop and are objectively efficient ensuring good conservation of both artworks. It consisted of removing the previous cradle on the back by mechanical and chemical means. All the planks were separated to remove the old animal glue that was no longer effective. The planks were reassembled by applying new animal glue and inserting missing dowels.

For each panel painting a new auxiliary cradle had to be adjusted at the back in order to hold the planks together and permeate to control unwanted stresses causing damage. For panel N°1 the cradle was designed on the basis of empirical experience and technical literature, permit lateral displacement of the planks (Figure 3). For panel N°2 the cradle was designed with a self-tensioning spring system also permit out of plane displacements, following the analysis of several scientific data collected during the first four of the six years of the study, which made it possible to define the hygro-mechanical behavior of the artwork and that of the new cradle (Figure 4) (Mazzanti and al. 2020).

3. Methods of study

The panels' studies were carried out in a hermetic showcase, glazed on both sides and equipped with a relative humidity control system, in order to characterize the response of the different structures (panel and cradle, old or new) to hygro-thermal variations. The shape, the curvature variations and the strains on the surfaces of the panels were measured on both sides using a non-contact optical method (Dupré et al. 2020). It's important to say that before being subjected to any experimental procedure the condition of the paint layers was inspected and verified by a paint conservator.

A team of three universities of science and technology (Poitiers (F), Florence (I), Montpellier (F)) and also independent researchers (Nth, F) ensured the elaboration of the methodology adopted. The tests were carried out after remedial conservation of panel N°1 instead of before, during and after remedial conservation of panel N° 2.

To measure 3D displacements, a stereo image acquisition was used, coupled with a mark tracking technique and digital image correlation method for the image analysis. The choice of the image analysis depends on the contrast of the surface. On one hand, the mark tracking technique consists in detecting and following some dots (black or white) on the surface during the shape variation. On the other hand, the correlation methods require a texture on the surface (natural in the case of panel N°1, i.e. the paint layer) in order to follow several small areas by a local matching between two images of different mechanical states. In both cases, the natural contrast is not sufficient on the back side but also on the

front side of panel N°2, where small round marks (Japanese paper reversibly glued with a weak adhesive) have been placed on the two sides and the mark tracking technique has been used. Images of the panels were taken every 30 minutes and recorded on a computer.

At the same time, the weight of the structure was measured and recorded during the variations of relative humidity inside the showcase, in order to assess the absorption and the loss of moisture by the artwork. (Dupré and al. 2020)

The long-term observation of panel N°2 has allowed us to better understand how the damage to the wooden support occurred, its impact on the wooden structure and how previous restorations have altered its mechanical behavior (Dupré and al. 2017; Jullien and al. 2020; Jullien and al. 2021). The study of panel N°2 helped to refine the conservators' initial remedial proposal for conservation and design a new cradle with self-tensioning spring system based on technological science, which will ensure preventive conservation on this panel. The study of panel N°1 is currently underway. It is expected to characterize its' existing new cradle, manufactured in 2011 and possibly complete the study carried out on the panel N°2 between 2016 and 2023.

4. Phases of analysis

Measurements were carried out on the panels in different configurations in order to characterize the response of the different structures to hygro-thermal variations.

During each experimental phase inside the hermetic showcase, the relative humidity (RH) was programmed as far as possible to identical cycles of increase and decrease of about 10 +/- 5% RH between 50 and 65% RH. The paintings were monitored during several stages and these RH cycles at a constant temperature which was around 24°C due to the equipment installed in showcase.

For *The Holy Trinity Crowning the Virgin* (panel N° 2) most of its constituent materials have been identified and characterized by chemists and other research laboratories. The measurements were recorded in various configurations:

- The panel with the old cradle and frame: stabilization at 55% RH then 65%
- The panel with the old cradle, without the frame: 65% RH then 55% RH and stabilization
- The panel alone, once the old cradle was removed by the conservators: same as above, during different time lapses and complementary tests.
- The panel with the newly designed cradle, before and after the restoration of the paint layer: same as above during different time lapses and adjustment of the cradle's tension.

The Life of Holy Agnes (Panel N° 1) was also examined in the same showcase but only during the last phase.

The measurements were taken in the following configurations:

- The panel with the new cradle, after remedial conservation and restoration of the paint layer: from 60% down to 55% RH until stabilization
- Same configuration 55% RH then 65% and stabilization

5. Results and discussion

The mechanical behavior of the two panels, after remedial conservation, shows interesting differences during variations of relative humidity.

The panel N°1 (Figure 5) reaches a maximum slight 0.4 mm curvature 2 days after the 10% change of humidity; 13 days later, this curvature disappears, due to the equilibrium of the moisture in the panel. The horizontal strain reaches about 0.12% in 27 days. The panel N°2 (Figure 6) curvature of 1.5 mm 4 days after the 10% change in humidity; it takes 30 days to the panel to reach its moisture equilibrium and thus the curvature to disappear. The maximum horizontal strain, 0.15%, is obtained in 53 days. The maximum curvature is higher for panel N°2. Several factors may influence this difference: the

dimensions of the panels (panel N°2 is 1.2 times larger), their thickness (panel N°2 is 0.6 times thinner) and the type of connection between the cradle and the panel (panel N°2 has self-tensioning springs). The durations to reach the maximum curvature and the moisture equilibrium are higher for panel N°2. Panel N°1 is thinner, it should reach its moisture equilibrium faster. That is not the case. The difference may be due to the permeability of the back surfaces: panel N°2 has a coating on the back side whereas panel n°1 doesn't, and moreover presents xylophagous holes counted on 15% of the surface. The characteristics of the paint layers may also have an influence. The maximum horizontal strains are slightly higher for panel N°2, that may be due to the specie of wood, this tendency agrees with the coefficients of oak and lime given in the literature (total tangential shrinkage coefficient: lime 9%; oak 10%).

Panel N°1 shows a smaller maximum curvature. We assume that stresses are then greater because of restrictive movements. The cradle with springs allows more movements. The next step in the study will be to add springs to the cradle of panel N°1 to compare these behaviors, and deduce the effect of the springs.

7. Conclusion

After analyzing the monitoring data from the two panels, it seems necessary to multiply the cases. For example, choose different panels with different types of auxiliary cradles or secondary supports, or different essences of original wooden supports. Combine studies of the panels with those existing on canvas and study in a more general way study the climate in the exhibition rooms in relation to that outside and, overall, the effect on works of art made of organic materials. Then relate this to works made of metal and also to biological or chemical degradation.

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Materials list

- Springs Smalley (<https://www.smalley.com/wave-springs/crest-crest-shim-ends>)
- IDS UI-3480CP-M-GL high resolution monochrome camera, 1/2", 2560 x 1920 pixels²
- Industrial scale SARTORIUS, Combics Series, type CAW1P-1-60ED-I, maximum load: 60 kg, accuracy: 2 g
- CEAM Preservatech, MiniOne, <http://www.preservatech.com/>
- deformometric Kit, GESAAF, University of Florence

Contribution by each author

M. Bousvarou initiated and participated in the scientific study and discussions, obtained funding, coordinated the different teams, participated in writing the article

D. Jullien initiated and participated in the scientific study and discussions, coordinated the scientific teams, participated in the analysis of the results and in the writing of the article

J.C. Dupré initiated and participated in the scientific study and discussions, conducted the image correlation measurements, participated in the analysis of the results and in the writing of the article

G. Tournillon did the remedial conservation of wooden supports, initiated and participated in the scientific study and discussions

Figures

Figure 1. The Life of Holy Agnes, (1) front and back (2) side after restoration, ©CICRP- Emilie Hubert-Joly

Figure 2. The Holy Trinity Crowning the Virgin, (1) front and back (2) side after restoration, © Danièle Amoroso

Figure 3. The new cradle for The Life of Holy Agnes designed by conservators: (1) design drawing, (2) wood structure, (3) sliding screw system, © Gilles Tournillon

Figure 4. The new cradle for The Holy Trinity Crowning the Virgin designed by conservators: (1) design drawing, (2) wood structure, (3) sliding screw and self-tension spring system, © Gilles Tournillon

Figure 5. The Life of Holy Agnes, RH variation, shape deformation and horizontal strain viewed from front side at different steps, ©Pprime

Figure 6. The Holy Trinity Crowning the Virgin, RH variation, shape deformation and horizontal strain viewed from front side at different steps, ©Pprime

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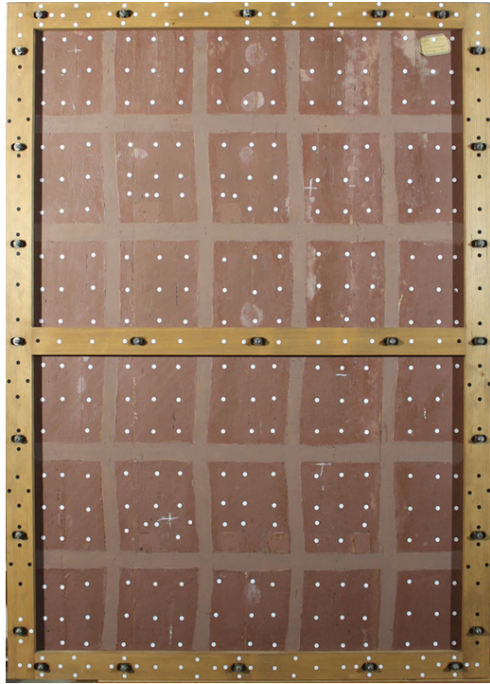
(1)
Fig1



(2)



(1)
Fig 2



(2)

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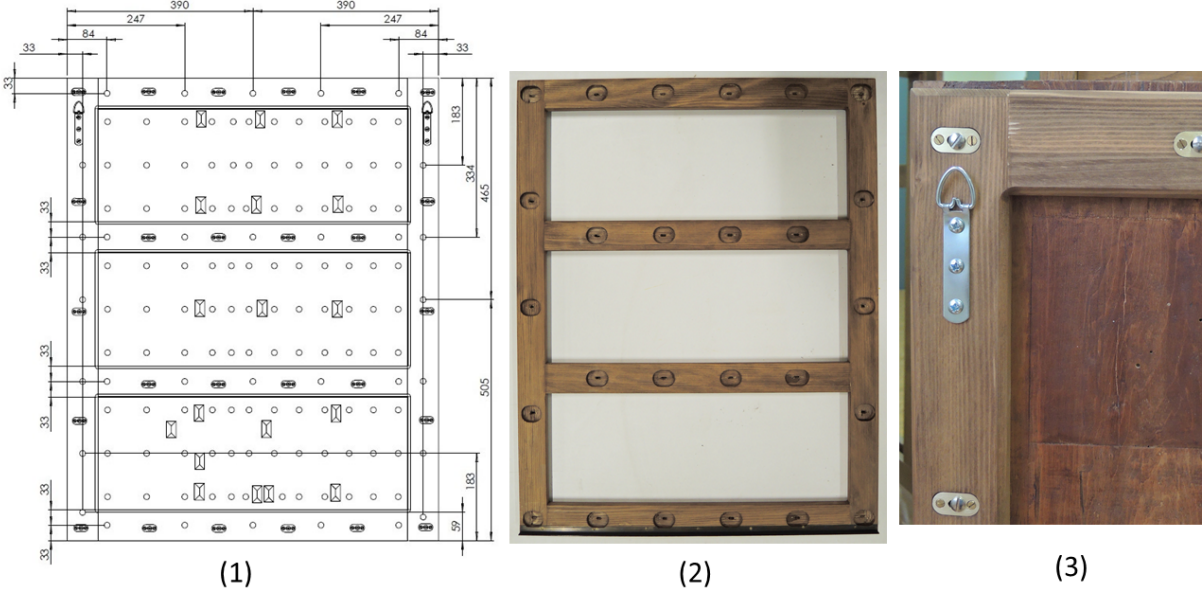


Fig 3

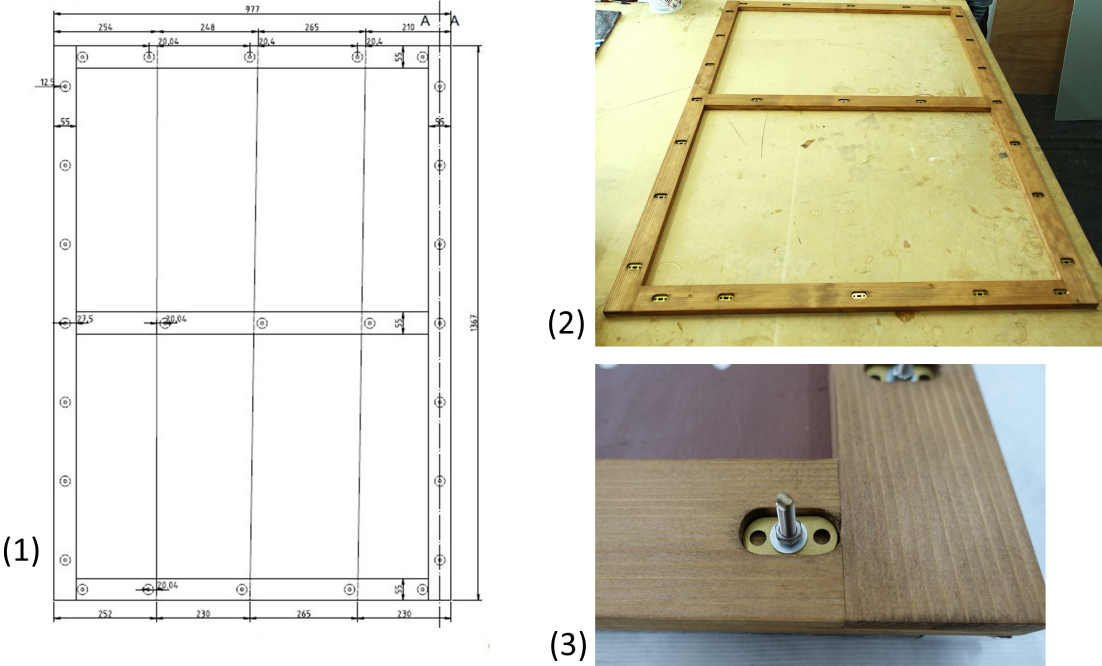


Fig 4

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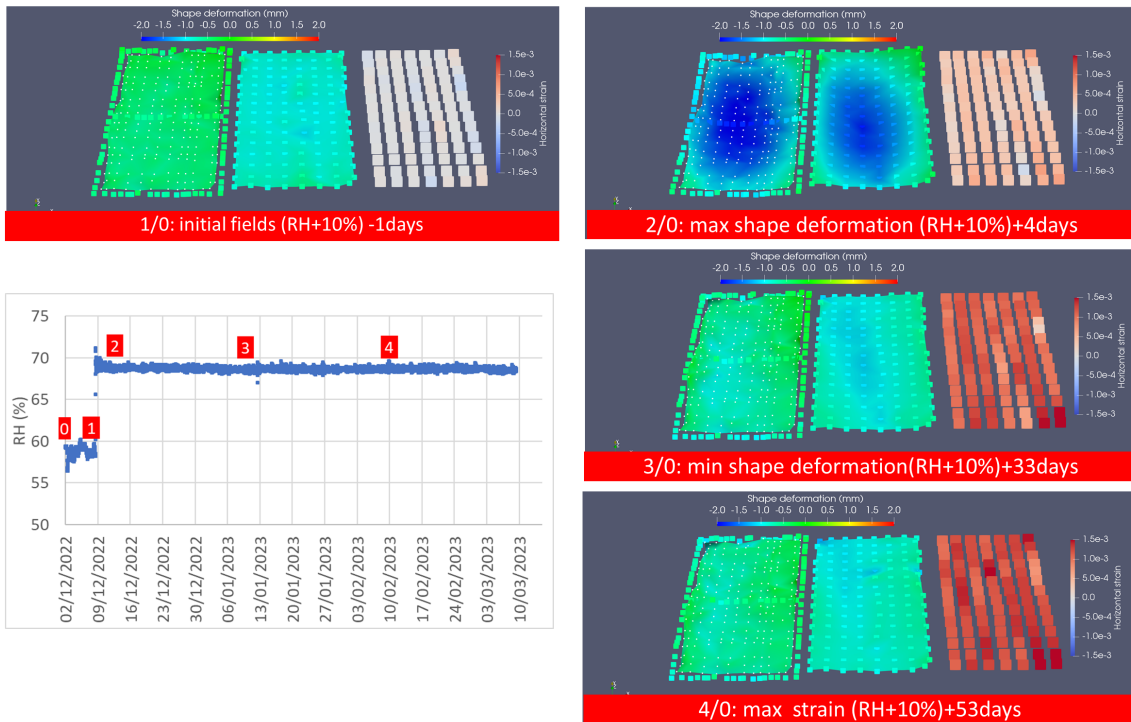


Fig 5

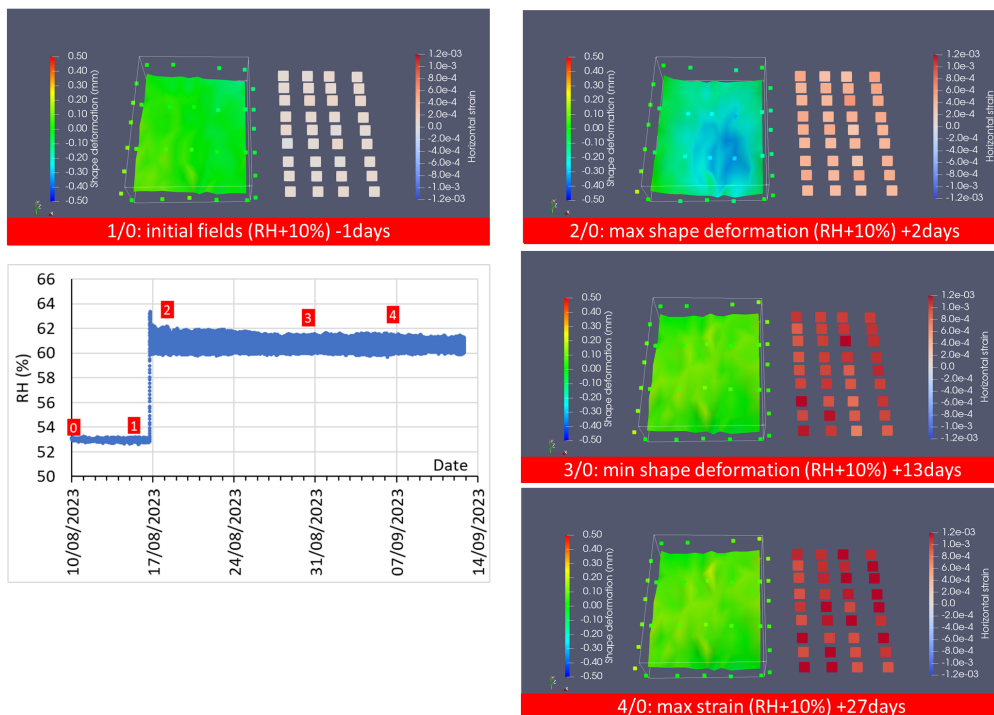


Fig 6