SCIRES it
SCIentific RESearch and Information Technology
Ricerca Scientifica e Tecnologie dell'Informazione
Vol 12, Issue 2 (2022), 109-119
e-ISSN 2239-4303, DOI 10.2423/i22394303v12n2p119

CASPUR-CIBER Publishing, http://www.sciresit.it

COLOUR CHARACTERISATION FOR THE RESTORATION OF A JAPANESE HANDSCROLL

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Abstract

In the restoration of painted artworks, the colour characterisation is a fundamental analysis to address the choice of suitable materials for the recovery and the consolidation of the painting layers. In this paper, we present a diagnostic study on a unique Japanese painted paper handscroll (emakimono), dated back between the late Edo (1603-1867) and the early Meiji (1868-1912) periods, preserved at the Museum of the Civilisation- Prehistoric Ethnographic Museum "Luigi Pigorini" in Rome (Italy). The artwork required an urgent restoration and the consolidation of the entire structure. In order to define specific interventions, non-destructive measurements by means of Fiber Optics Reflectance Spectroscopy (FORS) X-Rays Fluorescence Spectroscopy (XRF) were carried out on the artefact. The results allowed the identification of the colour palette used for tests on the chromaticity and the efficacy of the proper consolidants to employ in the restoration.

Keywords

Conservation Science, FORS, XRF, pigments, restoration, Japanese handscroll.

1. *Introduction*

Since prehistoric times, colour has been employed as an expression of creativity and means of communication. In painted Cultural Heritage (CH), colours are the main part of the artwork itself and they are an essential element of the artwork's materiality. The loss of such features leads to the decrease of the value and the power of the CH item. In the case of ancient manuscripts, coloured elements had the role of enriching the artefact and capturing the attention of the reader. Indeed, the colour appears in many types of decorations, like as small and colourful illuminations, typical of occidental mediaeval manuscripts (Plossi Zappalà, 1991), or as tool to describe the story itself, like in the oriental handscroll here investigated. The studied artefact is classified as *emakimono*, that means "horizontal painting to unroll" (Okudaira, 1962) and it is characterised by a particular decorative apparatus with a rich coloured palette which presented several conservation problems, such as the loss of adhesion of the pigments. Thus, a non-destructive diagnostic survey based on the colour identification was essential in order to design the best restoration approach to consolidate the paint layer to the substrate and to create the conditions suitable for the museum exposition. For these reasons, Fiber Optics Reflectance Spectroscopy (FORS) and X-Rays Fluorescence Spectroscopy (XRF) were employed on the handscroll for the colorimetric and qualitative evaluations of pigments through the analysis of the characteristic spectra and chemical responses (Aceto et al., 2014; Clarke et al., 2021; Idjouadiene et al., 2021; Leona & Winter, 2001). The used approach was chosen due to the FORS technique capability to obtain non-destructive and quick colorimetric measurements for the evaluation of the occurancy of any chances in colour or whiteness in the artwork. In addition, the prototypal XRF system employed allowed punctual analyses and chemical characterisation of the colours also where the pigments powder was inhomogeneous. The complementarity of these methods allowed to obtain the colour characterization of the investigated *emakimono* and the identification of the pigments, which are coherent with the historical-artistic period of the handscroll.

Finally, the results were then used for the elaboration of a laboratory mockup with the aim of studying the behaviour of different types of consolidants to be applied to the pigments and evaluating the behaviour of the adopted materials, also artificial aged, with the final goal of planning the most adequate intervention procedure.

2. The Japanese handscroll

The handscroll object of this study is entitled Jizō Engi Jō (地蔵縁起、上) and it is the volume one of the Legend of Jizo referred to the history of the Yata temple in Kyoto. Such an artwork is a Japanese *emakimono* executed in ink and paint on paper, part of the Vincenzo Ragusa's Collection owned by the Civilization Museum in Rome. The scroll is a XIX century copy of a XIV century work, known as Yata Jizō Engi, composed by two handscrolls (jo and ge, volume one and two) that is believed to be written by the Japanese poet Fujiwara no Ietaka in the early Kamakura period and probably illustrated by the famous painter Takashina Takakane. The 14th century handscrolls are still preserved at the Yata temple in Kyoto and they are considered as Important Cultural Property. The Jizō Engi Jō *emakimono* is dated approximately back to the 1870 decade thanks to a brief text written on the last sheet of the scroll. Such text refers to the purchase of the object for export purposes during the seventh or tenth year of the Meiji era (respectively 1874 or 1877) and it is accompanied by a seal of the Japanese antique dealer Ninagawa Noritane. The artwork was indeed purchased by the Italian artist Vincenzo Ragusa who lived in Tokyo between 1876 and 1882. Between 1888 and 1916, the Italian artist sold his collection to the Royal Luigi Pigorini Ethnographic Museum in Rome and nowadays it is preserved at the Museum of Civilizations.

The handscroll belongs to the *Engi-e* genre, a label that applies to a wide range of textual and painting materials, especially referring to the histories and legends of Buddhist temples and shrines. The *Jizō Engi Jō* narrates part of the legends relating to the Yata-dera temple principal deity, the *Bodhisattva Jizō*, and it illustrates the journey of the High Priest Manmei to the Reign of King Enma (one of the ten kings of the Buddhist Hell), where the monk admires the Bodhisattva's benevolence towards the souls of the damned, who can be saved from the torments of Hell just with Jizo's intercession.

The illustrated scenes, which adorn most of the handscroll, are painted in a Japanese style typical of the late 14th century, called Yamato-e. The absence of geometric perspective and the use of overlapping layers of colours outlined by thin brushstrokes are some of the elements that characterise this pictorial style.

The first sheets of the scroll contain a text in Chinese language written in black ink (sumi), that contains an introduction to the narrated events and links the foundation of the temple to the will of Emperor Tenmu (631-686). Furthermore, short texts written in Japanese are interspersed among the paintings. The structure of the Engi *emakimono* realised on paper differs in some features with the respect to the most known Japanese handscrolls. Paintings mounted in this format are meant to be unrolled horizontally (from right to left) and viewed by one person at a time, who, while unrolling the scroll with the left hand, should roll up the section just viewed with the right one (Fig. 1). Therefore, the materials of which handscrolls are made must be flexible yet robust, qualities both owned by Japanese paper and silk. They are usually made up by various sheets of paper (more rarely silk) lined and joined together with a system of backing layers of Japanese paper, wrapped around a roller attached to the left end (Radeglia & Quattrini, 2014; Winter, 2008). Due to the "functional" destination of use of Japanese artworks and the nature of the material employed in the making of such artistic artifacts (Wills, 1985), it is well known that Japanese scrolls often require periodic conservation treatments and substitution of the lining, thus they are rarely found in the original state: therefore, the historical significance of the treated painting is enhanced by the preservation state of its original conditions.

Fig. 1: Detail of the Jizō Engi Jō handscroll.

The *Jizō Engi* measures approximately 35 cm in height per 10 m in length and its structure is composed by a cover, the outermost sheet (*hyōshi*) and at its right end is attached the *hasso*, a traditional bamboo wooden stick that allows the correct closing system of the handscroll. Four sheets (35cm x 25cm) are attached to the *hyoshi* that contain the Chinese text, followed by 32 sheets containing the painting and brief texts, these sheets constitute the *honshi* of the scroll (Winter, 1985). The *honshi* is backed by one layer of lining made by a series of paper sheets of *kozo* paper (Priori & Quattrini, 2005; Quattrini et al., 2014). A wooden rod with red lacquered ends, *jiku*, is attached to the outermost part (left edge) of the last sheet of the handscroll, that is the rod around which the entire scroll is rolled.

2.1 Conservation issues

Because of the peculiar ways of conservation of handscrolls, which are typically preserved by being rolled up, the *emakimono*'s paintings usually do not suffer much from photochemical damages caused by the exposure to light. Nevertheless, they are consistently subjected to mechanical and physical stresses induced during the consultation and manipulation. The state of conservation of the coating of the paper supports, traditionally made of a mixture of animal glue (*nikawa*) and alum, known as *dosa*, contribute significantly to the conservation of the pictorial film of this kind of works of art. *Dosa* used as coating reduces the porosity of the paper surface, making it more resistant to hygroscopic variations, but it can also prevent pigments and colours from penetrating into the painting supports.

The *Jizō Engi* handscroll has never been restored before and the conservation assessment of the work revealed several damages of the paper support, such as material losses, foxing along the edges and horizontal creases probably due to the wrong handling of the object. Nevertheless, the structural qualities and the mechanical properties of the support were to be considered in discrete state of conservation. On the other hand, the dehydration and the ageing of the media's binding determined its loss of functionality hence causing losses, flaking of the pictorial surface and the incoherence of the pigments in many areas of the handscroll, requiring an urgent consolidation procedure. Extended losses affected the areas painted in blue, while the green details of the illustrations were often affected by the flaking of the most superficial layers of paint. The areas of the paper support near the reds showed the abundant presence of particles of pigments detached from the painting surface and the same dusting and incoherence affected the orange painted details.

3. Analysis

In order to characterise the colour palette of the *emakimono* for the identification of the proper materials for the restoration, a combined approach was applied by performing non-destructive FORS and XRF measurements on the artwork. The results were then used for the elaboration of a test sample with the aim of evaluating the effects caused by the artificial ageing of consolidants and pigments.

3.1 FORS

Reflectance spectra were recorded with a StellarNet GREEN-Wave spectrometers equipped with a D65 illuminant for measurements within the range of 350-1150 nm. The instrument is optically coupled by means of fibre to a cube with an internal integrating sphere able to measure an area with a diameter of 1 cm^2 (*StellarNet FORS Systems*, 2021). The calibration of the system was performed using a reference target with a >97% certificated reflectance to the light from 300-1700 nm. The measures were performed arranging the probe on the handscroll in correspondence of the colours indicated in the sampled points in Fig. 2.

Fig. 2: Sampled points with FORS technique.

Then, the acquired spectra were compared with the available database (Aldrovandi et al., 2020) in order to identify the pigments by their characteristics reflectance spectra.

Further investigations were conducted on the paper support for characterising its chromatism and whiteness with the aim of verifying the effectiveness of the cleaning procedure. Such evaluations were carried out by calculating the differences in colour ($\Delta E_{L^*a^*b^*}$) and in whiteness ($\Delta W_{L^*a^*b^*}$) (Ganz & Pauli, 1995; Oleari, 2008) before and after the restoration procedures.

3.2 XRF

The XRF spectra were acquired in the same points of the FORS measures by using the "Rainbow X-Ray" (RXR) experimental station developed at the XLab Frascati of the Istituto Nazionale di Fisica Nucleare–Laboratori Nazionali di Frascati (INFN-LNF) (Hampai et al. 2015; Cappuccio et al. 2021). The RXR layout is dedicated to advanced X-ray micro-fluorescence studies on 2-or 3-dimension stages (2D/3D μXRF), being equipped with polycapillary lenses in a confocal geometry (Cappuccio et al., 2021; Hampai et al., 2015). The system is based on a full lens PolyCO for the primary beam, with parameters corresponding to the input focal distance (IFD) of 58.5 mm, the output focal distance (OFD) of 42 mm, the length of 120 mm, the input diameter of 4 mm and a 90 μm focal spot size. This configuration allows RXR to perform elemental depth profiling for different types of the samples (Cappuccio et al., 2018). Moreover, the confocal approach simplifies the measurement procedure and allows discriminating depth-dependent signals from high to low Z elements avoiding negative superposition of images. The core of RXR (Fig. 3) is based on the measurement head (a monolithic Al block) in which the various components inserted are: an X-ray tube (Mo, 50 kV - 1 mA) with a focusing PolyCO, two detectors (one combined with a PolyCO for confocal measurements), an optical microscope with CCD camera.

Fig. 3: RXR experimental setup.

The xyz is a micrometric stage with the precision of 3 μm in the plane xy and 10 μm in z designed to enable XRF analysis of objects large up to 40x60x40 cm^3 with a weight up to 100 kg.

4. Results

4.1 Colours identification

The FORS spectra show the typical profiles of the analysed colours with a higher signal in correspondence of most homogeneous sampled areas, such as in the case of red pigment.

The different signal intensity between the green and yellow samples with respect to their references are probably due to pigment powder inhomogeneity, paper support and binder ageing effects.

The lower reflectance signal could be due also to the support and binder contributions. Comparing the spectra with the existing databases (Aldrovandi et al. 2020; Cosentino 2014), a recognition of the pigments was provided, as reported in Fig. 4.

The pigments identification was confirmed by the XRF analyses (Fig. 5 where the sampled points and the related XRF spectra are reported). The details of the experimental parameters were already reported in (Cappuccio et al., 2021).

In particular, the Fundamental Parameter Method (FPM) was applied to estimate the concentration (in %) of the chemical elements (reported in Fig. 6 and Tab. 1) revealed by micro XRF with the purpose of assessing the existence of a stoichiometric ratio, among the elements, which could confirm or not the presence of a specific pigment.

The values given in Tab. 1 derive from the application of a mathematical calculation used to estimate concentrations (Hampai et al., 2015) to which an approximation on the significant figures was applied.

These findings were coupled with the data coming from historical and literature knowledge about the scrolls and the artistic materials, confirming the coherence between materials and dating. The identified pigments of the analysed colours are summarised in Tab. 2.

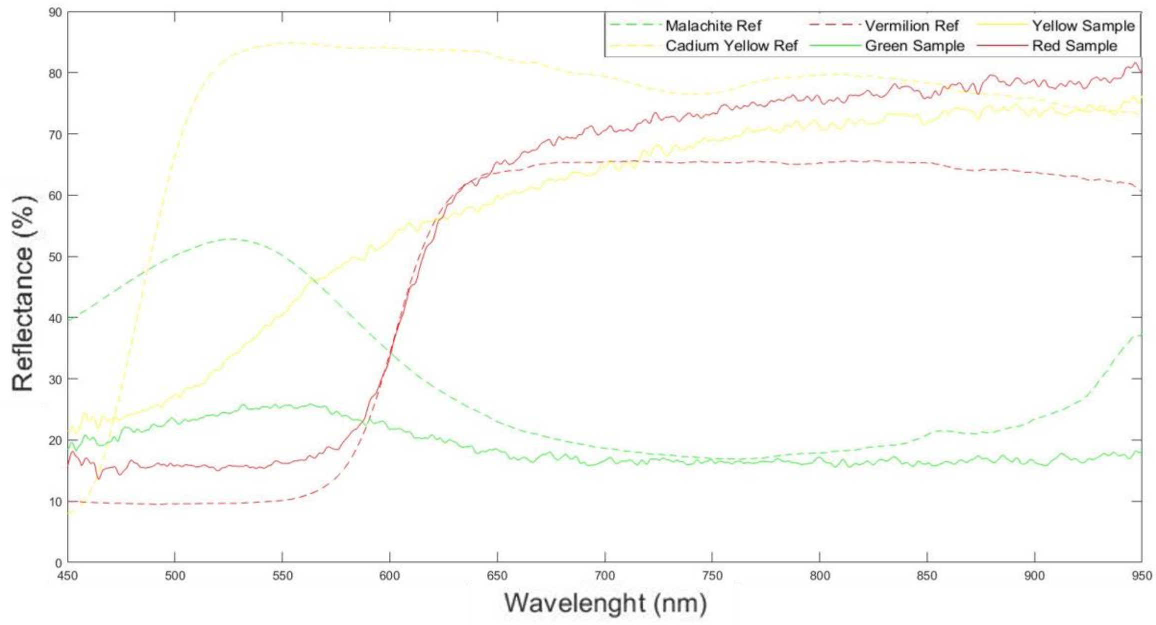

Fig. 4: FORS spectra of the sampled points on the handscroll of Fig.2 (the continuos lines) compared with the references (dashed lines) coming from the database (Aldrovandi et al. 2020).

Tab. 1: Concentration and error values (in %) of the chemical elements acquired in the points in Fig.5.

	Blue		**Light Blue**		**Brown**		**Green**		**Light Green**		**Root**	
Element	Conc. [%]	Err. Conc. [%]	Conc. [%]	Err. Conc. [%]	Conc. [%]	Err. Conc. [%]	Conc. [%]	Err. Conc. [%]	Conc. [%]	Err. Conc. [%]	Conc. [%]	Err. Conc. [%]
Al	0,00	0,00	3,14	0,15	2,09	0,25	12,85	0,67	8,71	0,68	3,10	0,22
Si	3,73	0,59	2,14	0,36	5,87	0,56	0,00	0,00	0,96	0,08	0,00	0,00
S	3,89	0,07	3,14	0,86	5,39	0,56	5,30	0,87	1,94	0,28	9,10	0,24
Cl	4,05	0,14	0,00	0,00	0,00	0,00	0,00	0,00	1,85	0,25	1,07	0,13
K	52,02	0,61	62,00	5,70	25,22	0,66	2,66	0,14	3,95	0,14	10,62	0,30
Ca	32,87	0,67	21,90	1,22	48,09	0,46	28,23	0,18	38,04	0,17	72,56	0,36
Ti	0,41	0,01	0,60	0,01	0,92	0,01	0,90	0,03	0,27	0,02	0,30	0,00
Cr	0,00	0,00	0,00	0,00	0,30	0,00	0,37	0,00	0,01	0,00	0,17	0,00
Mn	0,08	0,00	0,13	0,01	0,20	0,00	0,58	0,01	0,31	0,00	0,11	0,00
Fe	1,54	0,01	2,84	0,08	11,40	0,03	7,12	0,04	4,00	0,03	1,65	0,01
Co	0,78	0,01	2,32	0,24	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Ni	0,28	0,00	0,67	0,01	0,08	0,01	0,19	0,01	0,00	0,00	0,03	0,00
Cu	0,00	0,00	0,20	0,02	0,20	0,00	34,73	0,05	36,83	0,08	1,10	0,00
Zn	0,05	0,00	0,07	0,01	0,14	0,00	4,69	0,11	2,22	0,08	0,11	0,00
Pb	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00
As	0,20	0,00	0,76	0,17	0,00	0,00	2,38	0,01	0,91	0,00	0,00	0,00
Sr	0,10	0,01	0,09	0,02	0,10	0,02	0,00	0,00	0,00	0,00	0,07	0,01

Fig. 5: microXRF spectra of the sampled points obtained by RXR.

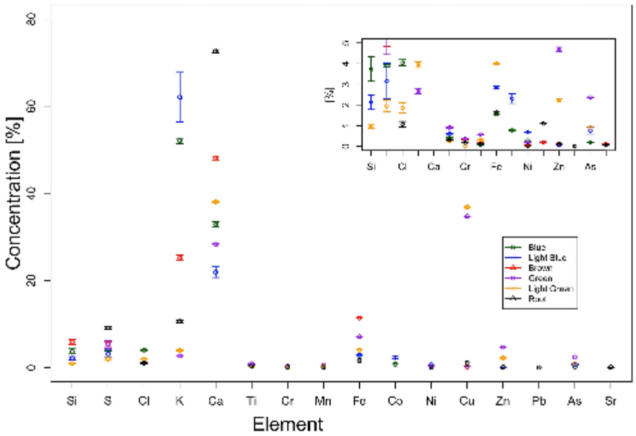

Fig. 6: Concentration of chemical elements from the sampled points obtained by analysing the XRF spectra with the FPM approach

Tab. 2: Identified pigments

Colour	Chemical formula	Identified pigment
Red	HgS	Cinnabar/Vermilion
Green	$Cu_2(OH)_2CO_3$	Malachite
Blue	$FeK[Fe(CN)_6$	Prussian blue
Orange	Pb_3O_4	Red Lead/Minium

In order to evaluate any changes in the chromatism (ΔE) and the whiteness (ΔW) of the paper support after the restoration and the consequent effectiveness of the cleaning procedure, further FORS measures were performed before and after the cleaning in different areas of the handscroll, where no colours were present. The results are reported in Tab. 3. It is worth to note that the minimum value associated with a difference in colour perceived by the human eye is 2. In many of the treated areas, significant variations were measured in term of colorimetric parameters and brightness of the supports. In most cases, the effects of cleaning, appreciable to the naked eye, were confirmed by values of ΔE between 3 and 12. Moreover, a general increase in the whiteness parameter (ΔW) was observed, confirming the effectiveness of cleaning process.

Tab. 3: chromatism (ΔE) and the whiteness (ΔW) evaluation in different points of the paper support of the handscroll.

	Point 1	Point 2	Point 3	Point 4
ΔE	3.0	5.0	12.0	10.0
ΔW	17.0	18.0	53.0	59.0

4.2 Test sample

The above-described results were used for the preparation of a laboratory sample on which further tests were performed for the identification of the best consolidant to apply during the restoration, by evaluating any chromaticity variations due to an artificial ageing process induced on the sample. Such an artificial process was performed for 17 days within a climate chamber at a temperature of 80° C and humidity values between 65-70 %. For the evaluation of the effects caused by the ageing of the consolidants on the sample, the variations of chromatism (ΔE) and, in this case, lightness (ΔL) were considered. The assessment of such parameters has the purpose to verify the consolidants inability to alter the refractive index and the chromatic characteristic of the media (i.e., that it must not shine, dull or yellow the surface). The laboratory mock-up was prepared using powdered mineral pigments mixed with Nikawa glue, applied on a support made of two layers of Japanese paper sized to simulate conditions and materials as similar as the original ones. The paint samples were then treated with the following consolidants (Hummert et al., 2013):

- Klucel® G prepared in alcohol solution with a concentration of 1%,
- Funori at 0.5% concentration in water solution,
- Nikawa glue at 1% concentration.

As can be noticed by the data shown in Tab. 4 for the green colour, the best results were obtained with Funori and Nikawa glue. In both cases, the smallest variations of the parameters were measured, corresponding to changes not perceptible to the eye.

Tab. 4: chromatism and lightness parameters measured on the mock-up after artificial ageing.

Consolidants	ΔE	ΔL
Klucel® G (1%)	5.4	1.1
Funori (0.5%)	4.1	0.8
Nikawa glue (1%)	3.6	0.7

Thus, considering the smallest values of ΔE and ΔL, the best consolidant considered suitable for the restoration of the handscroll was the Nikawa glue. The latter is the same adhesive traditionally used as binding and whose properties of flexibility, chemical stability and compatibility with Oriental artefacts and paintings are beginning to be acknowledged even in the Western conservation culture (Radeglia & Quattrini, 2014).

5. Restoration

Preliminary analytical tests and analysis conducted on the artefact have allowed to gain information about the materials employed in the Jizo Engi scroll and the traditional methods of handscroll manufacturing, being of crucial importance for the definition of suitable conservation treatments. The structure and the paper support of both the primary and the backing layers were in discrete state of conservation so that a new lining of the artwork was not required. Such an important aspect has allowed the preservation of the original materials and structure of the handscroll and the limitation of infill and mending treatments, only localised areas of the paper support. The latter has represented a challenge under other points of view (due to preventing eventual mechanical stresses).

The restoration treatment began with an accurate cleaning of the surface of recto and verso, employing materials and techniques tested on small areas of the paper support before the cleaning treatment. The effects on the paper surface were assessed thoroughly with the help of a portable digital USB microscope (Jiusion USB Digital Microscope). Smokeoff sponges and QVC polyurethane sponges were chosen to clean respectively the surface of the verso and recto of the handscroll (Daudin Schotte et al., 2011) (Fig.); the general aim of this step of the intervention was to remove incoherent dust and residues accumulated on the paper surface which usually are harmful carriers of fungi spores and pollution particles, while not altering the aesthetic properties of the artwork.

Fig. 7: Performing the cleaning treatment on an area of the recto of the artowork, using QVC poliuretane sponges.

Restoration of the paper supports followed the cleaning treatment: this step was aimed to consolidate the abrasions caused by a pregressive entomological attack and to repair tears and losses of the primary and secondary support, localised especially in correspondence of the first sheets of the handscroll on the top and bottom edges. Multiple infills to the paper support were required to adjust the thickness of the repairs to the one of the original paper support (Fig.).

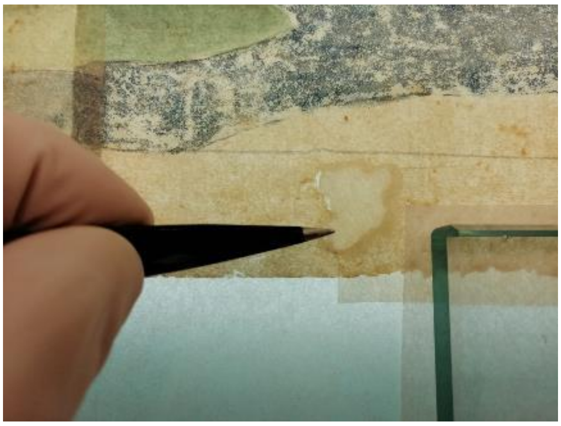

Fig. 8: Performing an infill treatment with Japanese paper and glue starch.

For the restoration treatments, starch glue is appropriately diluted and Japanese paper and tissue were used, adequately toned with watercolours. Tears caused by a pregressive housing system of the artwork, that had been hanging attached with metal pins, were repaired using Japanese tissue applied to the verso of the artwork, in order to maintain visible trace of the conservation history of the object, while assessing its consolidation. A large tear on the cover of the handscroll, in proximity of the hassō, required a different approach due to the more frequent and greater mechanical stresses to which the area is subjected: in this case different layers of Japanese paper were used.

The use of several layers of paper allowed the recovery of the integrated structure of the handscroll cover and the repairing of gaps, as can be seen in Fig. 9 and Fig. .

Fig. 9: The cover of the handscroll where a large damage is localized in proximity of the *hasso* (red rectangle) and many damages are dispersed on the surface (blue arrows).

Fig. 10: The cover of the handscroll after the conservation treatment.

For the consolidation treatment on the pictorial surface, a procedure was developed with the aim of avoiding any significant alteration on both the aesthetic and the mechanical properties of the paper support. The best consolidant for such application was studied in the laboratory tests and it was identified as the nikawa glue solution at 1% of concentration. The consolidant was applied to the surface of the painting through a compressed air sprayer, delimiting the treatment to the specific areas of the handscroll which presented decoesion and losses issues. For such application, paper masks were cutted out to isolate the damaged painted areas and to avoid as much as possible the dispersion of the adhesive over the support and the colours that did not require a consolidation treatment (Hummert et al., 2013)(Fig.).

Fig. 11: The consolidation treatment on the green and blue painted areas using a paper mask for its application.

During the drying process the paper support was kept under light weights and a light tension with the help of some magnets to keep the surface plain, as can be seen from Fig. 6.

Fig. 6: Light weights and magnets used to keep the paper surface plain during the drying process.

The artwork was kept under constant observation to monitor its conditions and to verify that did not occur any deformation or mechanical alteration of the paper support.

6. Conclusions

A colorimetric survey was performed on a colourful and written modern copy of a 14th century Japanese handscroll entitled Jizo Engi Jo. At the moment of the study, the 19th artwork presented several adhesion issues, mainly regarding the pigments, so that an urgent restoration procedure was needed. The results of FORS measurements allow the characterisation of colour palette of the handscroll, identifying the pigments used for the preparation of a laboratory mock-up for the identification of the best consolidants to employ to avoid further detachments of the pictorial apparatus of the Japanese handscroll. The outcomes of the presented work proved to be of great valuable for the characterisation of the materials of a particular oriental artefact as well as for the confirm of their historical reliability, coherent with the handscroll dating. Furthermore, the application of the results on the elaboration of a laboratory sample for the evaluation of the best consolidation materials showed the usefulness of the proposed approach in conservation and restoration fields.

Acknowledgments

The authors would thank Dr. Loretta Paderni, Director of the Asian Department at National Prehistoric Ethnographic Museum Luigi Pigorini-Museum of Civilization, Prof. Laura Micheli from the Chemistry Department Laboratories of the University of Rome Tor Vergata for the artificial ageing of the samples and Prof. Luca Milasi from the University of Rome “La Sapienza” for the translation of the texts of the scroll.

References

Aceto, M., Agostino, A., Fenoglio, G., Idone, A., Gulmini, M., Picollo, M., Ricciardi, P., & Delaney, J. K. (2014). Characterisation of colourants on illuminated manuscripts by portable fibre optic UV-visible-NIR reflectance spectrophotometry. *Analytical Methods*, *6*(5), 1488–1500. https://doi.org/10.1039/c3ay41904e

Aldrovandi, A., Casini, A., Altamura, M. L., Cianfanelli, M. T., Riitano, P., Cagnini, A., Galeotti, M., Picollo, M., Radicati, B., Agostini, A., Andreucci, D., & Stefani, L. (2020). *Fiber Optics Reflectance Spectra (FORS) of Pictorial Materials in the 270-1700 nm range*. SABeC IFAC-CNR.

Cappuccio, G., Dabagov, S. B., Guglielmotti, V., Hampai, D., Martini, M., Mazzuca, C., Micheli, L., & Redi, M. (2021a). PolyCO in XRF analysis: Fundamental Parameter Method applied for Japanese Buddhist scroll studies. *Radiation Physics and Chemistry*, *188*, 109660. https://doi.org/10.1016/J.RADPHYSCHEM.2021.109660

Clarke, M. L., Gabrieli, F., Rowberg, K. L., Hare, A., Ueda, J., Mccarthy, B., & Delaney, J. K. (2021). Imaging spectroscopies to characterize a 13th century Japanese handscroll, The Miraculous Interventions of Jizō Bosatsu. *Heritage Science*. https://doi.org/10.1186/s40494-021-00497-1

Daudin Schotte, M., van Keulen, H., & van den Berg, K. J. (2011). Analisi e applicazione di materiali per la pulitura a secco di superfici dipinte non verniciate. *Quaderni Cesmar7*.

Ganz, E., & Pauli, H. K. A. (1995). Whiteness and tint formulas of the Commission Internationale de l'Eclairage: approximations in the L*a*b* color space. *Applied Optics*, *34*(16), 2998. https://doi.org/10.1364/ao.34.002998

Hampai, D., Liedl, A., Polese, C., Cappuccio, G., & Dabagov, S. B. (2015). RXR: A new X-ray facility at XLab Frascati. *X-Ray Spectrometry*, *44*(4), 243–247. https://doi.org/10.1002/xrs.2614

Hummert, E., Henniges, U., & Potthast, A. (2013). Stabilisation treatments with aerosols: Evaluating the penetration behaviour of gelatine and methylcellulose. *Restaurator*, *34*(2), 134–171. https://doi.org/10.1515/res-2013-0008

Idjouadiene, L., Mostefaoui, T. A., Naitbouda, A., Djermoune, H., Mechehed, D. E., Gargano, M., & Bonizzoni, L. (2021). First applications of non-invasive techniques on Algerian heritage manuscripts: the LMUHUB ULAHBIB ancient manuscript collection from Kabylia region (Afniq n Ccix Lmuhub). *Journal of Cultural Heritage*, *49*, 289–297. https://doi.org/10.1016/J.CULHER.2021.03.008

Leona, M., & Winter, J. (2001). Fiber optics reflectance spectroscopy: a unique tool for the investigation of Japanese paintings. *Studies in Conservation*, *46*(3).

Okudaira, H. (1962). *Emaki: Japanese Picture Scrolls*. Charles E. Tuttle.

Oleari, C. (2008). *Misurare il colore*. Hoepli (Ed.).

Plossi Zappalà, M. (1991). La miniatura medievale su pergamena: la tecnica, i pigmenti, il supporto. *Kermes*, *12*.

Priori, G. F., & Quattrini, M. V. (2005). La caratterizzazione delle carte orientali. In *Bollettino ICR Nuova Serie* (pp. 134–150).

Quattrini, M. V., Ioele, M., Sodo, A., Priori, G. F., & Radeglia, D. (2014). A seventeenth century Japanese painting: Scientific identification of materials and techniques. *Studies in Conservation*, *59*, 328–340.

Radeglia, D., & Quattrini, M. V. (2014). *Il rotolo giapponese Bamodoizu - The Japanese Bamodoizu roll* (G. Editore (Ed.).

StellarNet FORS systems. (2021). https://www.stellarnet.us/systems/color-measurement-systems/

Wills, P. (1985). Far Eastern Pictorical Art: Form and Function. *The Paper Conservator*, *9*(1), 5–12. https://doi.org/10.1080/03094227.1985.9638464

Winter, J. (1985). Paints and supports in Far Eastern Pictorical Art. *The Paper Conservator*, *9*(1), 24–31. https://doi.org/10.1080/03094227.1985.9638466

Winter, J. (2008). *East Asian paintings : materials, structures and deterioration mechanisms* (F. G. of Art, A. M. S. G. (Smithsonian Institution), & S. Institution (Eds.). Archetype Publications.