A window with different views. The conservation of the ivory windows of Sundari Chowk at the royal palace in Patan, Nepal

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Introduction

Since 2010, the Institute of Conservation of the University of Applied Arts, Vienna, has been involved in cooperative conservation campaigns in Patan, Nepal. So far there have been nine work missions organised during the summers of each year and they have intensified since 2015, as a reaction to the earthquake in April and May 2015.[1]

Patan's Durbar Square and the royal palace complex are UNESCO World Heritage Sites.[2] Since 1979, seven monuments and ensembles in the Kathmandu Valley have been registered on the World Heritage List of UNESCO.

The ivory window ensemble is located at the royal palace in Patan (figure 1), which is also named Lalitpur - the beautiful city.[3] The town, which is the oldest in the Kathmandu Valley, is famous for its beauty and for fine crafts like woodcarving and metal casting. These artworks are visible throughout the city, at the palace and the temples as well as at other buildings around the Durbar Square. The great architecture is a testament to the Malla rulers from the thirteenth to the eighteenth century AD.[4]

The royal palace, which was once the court of the Malla Kings, consists of three different courtyards: the Sundari Chowk, the Mul Chowk and the Manikeshav Narayan Chowk.[5] The Ivory Window Ensemble is an integral part of the facade of the Sundari Chowk facing onto Durbar Square and it is the main decoration of the whole building. The Sundari Chowk was built by order of King Siddhi Narasimha Malla in the year 1627 and was the residence of his family.[6]

Object description

The ivory window ensemble is located above the main entrance of the royal palace and overhangs the entrance at an inclined angle from the wall facade (figure 2). The window consists of three openings that are framed by a wooden construction decorated with carved ornaments. The wooden window construction is held together by a plug-in system and is composed of a variety of materials such as ivory, wood,[7] metal and textile. The ivory from the window ensemble was identified as the being from the Asian elephant (Elephas maximus indicus).[8]

The central window is made of fire-gilded repoussé copper and is flanked by two embellished ivory windows. Each of these measure 150 x 150 cm and both windows have almost the same design in composition and decoration.

Figure 1 Façade of the Sundari Chowk, facing the Durbar Square.

Figure 2 Front elevation of the window ensemble.

The embellishments, floral motifs and leaves as well as ornamental bands and pillars are made up of carved ivory. The window construction consists of wood and provides support for the ivory carvings which are fixed with iron nails to the support. In addition, some fine floral carvings are decorated with metal leaf beneath. The openings are flanked by wooden pillars which show textile wrapping under the ivory casing. The textile was probably used as a buffer against moisture. All surfaces of the windows are covered with a white secondary coating which has probably been applied as a protection against poor environmental conditions and also for aesthetic reasons.

Figures 3,4 Condition of the dismantled ivory window.

History and comparative samples

The window ensemble represents a very rare and precious example of Nepalese craftsmanship and it is the only one of its kind in the whole palace complex. The decorative motifs such as dragons and winged, angel-like figures, identified on the windows, suggest a probable date of about 1730.[9]
A similar decorated ivory window ensemble can be found in Kathmandu city, where it is built into the corner of the Hanuman Dhoka Palace´s facade. It was constructed for King Bhaskar Malla (1722-1734).[10] It contains five apertures, the middle one decorated with gilded copper repoussé and the left and the right windows with ivory. The carvings and embellishments at the Hanuman Dhoka Palace in Kathmandu are not as rich and delicate as the decorations of the windows in Patan.
The oldest window in this style was found in Bhaktabur at the Simhadvaradhvaka of Bhupatindra's Palace and is possibly dated to the end of the seventeenth century. Unfortunately, this window is no longer extant since it was destroyed by an earthquake in 1934.

Ivory - the material

Throughout the history of mankind ivory has been a very important and precious material. It has been used since the Palaeolithic age, about 100.000 years BC, mainly for sculptures and figures. Some of the oldest finds are small women and animal figures dating back to 30.000 BC.[11] The name ivory is only used for elephant and mammoth tusks, while mammoth ivory is also known as fossil ivory.[12]

A differentiation can be made between the tusks of the African and the Asian elephant. The tusks of the African elephant (Elephas africanus)[13] are bigger than those of its Asiatic counterpart. The African elephant's tusks are around 2–2.25 m long and are approximately 70–90 kilograms in weight. This kind of ivory is yellowish in colour, slightly transparent and its surface contains a characteristic patterning. African ivory is also called 'green ivory' because of its slightly greenish character. Being physically harder and more brittle than the ivory of the Asian elephants, it also cracks more easily. Since African ivory has the highest grade for hardness and thickness, it is very suitable for burnishing.

In the case of the Asian elephants (Elephas indicus)[14], only male animals grow tusks, measuring up to 1–1.5 m in length and weighing about 25–30 kilograms. Asian ivory has a white appearance, is more opaque and it yellows faster than its African counterpart. Since Asian ivory is a softer material containing a finer patterning, it is more workable in the sense of being engraved or cut, but cannot be polished as well as African ivory.[15]

Differences in colour and structure of ivory are dependent on many factors: elephant species, the animals' diet, age and breed, as well as the climate the animal has lived in.[16] The hardness of ivory depends on various factors, such as the distribution of minerals in the diet and climatic conditions. The tusk is harder when the climate is warmer and moister. The point of the tusk is the hardest part.[17]

There is also a difference between ivory and bone, namely in their structure: bone has blood vessels which look like little black dots, and ivory is usually whiter, harder and denser than bone.[18]

The primary component of the tusk is dentine. Dentine is a hard, calcareous tissue of whitish to yellowish appearance consisting of inorganic and organic components as well as water. The organic part is mainly based on protein collagen; 80% of the inorganic part consists of hydroxylapatite, calcium phosphate[19] and the remaining 20% is composed of magnesium phosphate, calcium carbonate and fluorides.[20] The water content of fresh ivory is about 20 to 25% while in dried ivory this decreases to between 13 and 15%.[21]

One of the main optical characteristics of ivory is the unique grain patterns known as Schreger Lines and Lines of Retzius.[22] These lines can help to identify if a piece is elephant or mammoth ivory.

Due to its chemical composition, namely the high portion of collagen, fresh ivory is a very hard and elastic material. During its ageing, the amount of collagen reduces and the ivory becomes brittle.[23]

Ivory is a highly hygroscopic material. To establish equilibrium between the moisture content in the ivory and the moisture in its environment ivory swells and shrinks with fluctuations in the relative humidity. As an organic material, it naturally undergoes ageing and deterioration processes. During drying and degradation of the collagen, the distinctive ivory pattern is released due to the decomposition of the material. Yellowing is also a kind of a natural ageing process, which is conditioned by chemical transformation of the collagen. This is visible in colour changes and the loss of flexibility. The main factors influencing the decay of ivory are relative humidity, temperature and UV light.[24]

Condition of the window ensemble

The overall condition of the ivory windows could be regarded as very poor, leaving the ensemble in jeopardy. The pinewood frames showed serious wet-rot and pest damage, and several wooden elements had lost their structural integrity. The carved timbers as well as the latticework were frequently broken or completely missing. The edges of beams were badly rotted and very brittle, some areas showed deep, long cracks, which was a sign of the wood´s desiccation. The wooden surfaces were covered with a white secondary coating, probably executed to imitate the lost ivory carvings. Thick layers of dust covered the whole surface of the windows, especially in hollow spaces. The layers of dirt adhered strongly to the wooden surface.

The ivory was also in very bad condition. There was only 20% to 30% of the original amount of ivory left and these remnants were badly degraded. Several factors causing decay could be identified: the overall presence of dust and dirt, the white coating, the loss of overall stability due to the fragile and porous surface, leading to a high number of missing parts (figures 3 and 4).

Ivory is unsuitable for exterior use, especially in a hot and humid climate. Extreme fluctuations of relative humidity and temperature force the material to expand and contract causing cracking and

Figure 5 Dust and dirt on the surface of the ivory carvings.

Figure 6 White coating on the ivory carvings.

splitting. Another reason for the deterioration and loss of the ivory were the iron nails used for fixing the embellishments to the wooden support. Iron has a different coefficient of thermal expansion than ivory, causing cracking and splitting in lengthways.[25]

The ivory's surfaces were covered with layers of dust and dirt, which penetrated deep into the ivory matrix and intermediate spaces. The fragile carved ivory pieces were, as already mentioned, covered with a white coating which had probably been applied as a protection against environmental impact. It could also have been applied to cover dust and dirt on the surface of the ivory carvings (figures 5 and 6).

To identify the white coating analyses were carried out using optical microscopy and scanning electron microscopy with energy dispersive X-rays.[26] The examination showed that the coating was composed of four different white paint layers (figure 7). In the bottom paint layer the pigment zinc-white was detected. This finding confirmed the assumption that the white coating is a secondary addition which can be dated, at the earliest, to the second half of the nineteenth century.[27] Due to the presence of the coating the fine ivory carvings were no longer visible and, moreover, the coating penetrated very deep into the ivory matrix.

The overall condition of the fire-gilded metal repoussé window was better. About 20% of metal elements were missing and the metal surfaces were covered by hard and dense dirt layers (figure 8). There were also several damages caused by mechanical forces that have led to major deformations in some of the metal parts. In addition some cracks were visible and some metal parts bent out of shape.

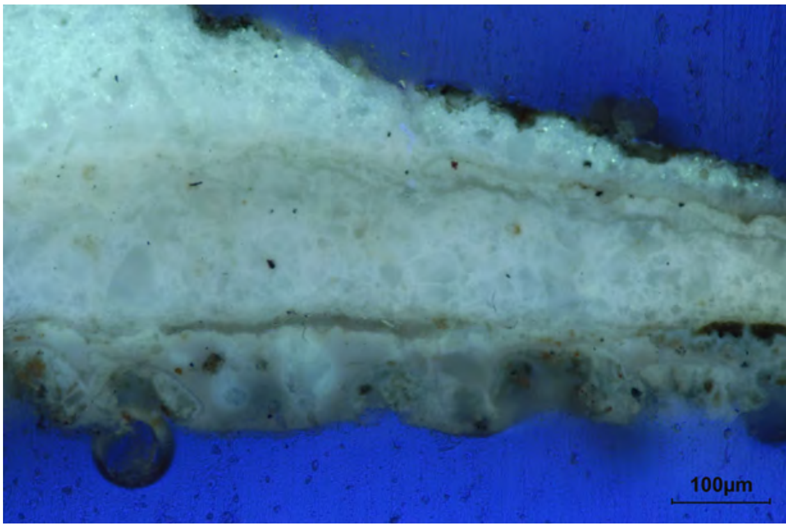

Figure 7 Cross-section of the white coating, reflected-light microscopy and UV light.

Figure 8 Condition of the central metal window.

Figure 9 Conserved central metal window, the gilded surface is visible again.

Aim and concept of the conservation treatment

The main aim of the conservation treatment is to preserve and protect the original substance of all three windows as an ensemble. This artwork is a very rare and precious item of highly sophisticated Nepalese craftsmanship and is of a great value for the Nepali community. Due to its poor condition a conservation treatment of the whole window ensemble had to be recommended.

The methodology for the conservation of this precious item was twofold: Firstly, the conservation and consolidation of the original ensemble and prevention of any further losses. It was also important to consider the condition of all three windows in order to achieve a unified and homogenous appearance of the ensemble after the conservation. Since it was decided not to reinstall the ivory windows into their original place on the facade, the making of replicas was proposed, with the original ivory windows being exhibited, after conservation, at the Patan museum, under stable climatic conditions. The conserved central metal window will be reinstalled on the facade together with the replica ivory windows.

Conservation treatments and reconstruction

The window ensemble was dismantled in spring 2013 and prepared for further conservation and preservation. The first step was to disassemble the construction into its individual parts for further treatments. Where it was possible, ivory carvings as well as metal applications were detached from the wooden support.

The wooden support

After the dismantling, all wooden beams were further disassembled for easier handling. Their surfaces were cleaned with rotating horse and goat hair brushes. Some parts were wet cleaned to remove the thick and hard layer of dirt. The white coating was removed mechanically with scalpels and glass fibre brushes as well as soft brushes. However, the white coating had to be left on some of the degraded parts. To disguise the white coating, these areas were retouched with water colours. The fragile and rotted wood was consolidated with 10% Paraloid B72 in acetone. After the consolidation the wooden surface was gently treated with acetone to remove the remaining acrylic resin from the surface. The broken wooden parts were glued with a PVA dispersion. Missing parts of the wooden frame were reconstructed by craftsmen from the local monument preservation office Kathmandu Valley Preservation Trust.

The metal window

All metal parts were dismantled from the wooden support for further treatment. Loose dust and dirt was removed with soft brushes. Afterwards, all the metal parts were cleaned with water and mild detergent (Pril). The hard, thick layer of grime was eliminated using a chelating agent which was applied with soft brushes, hard crusts were removed mechanically. After this treatment, the metal elements were rinsed with water to remove any remnants of the chelating agent. Some sensitive surfaces of the gilded repoussé copper were partly cleaned using a low frequency laser.[28] The deformed metal parts were reformed into their original shape by a local coppersmith with rubber and skin hammers and placed back onto the wooden frame. The missing parts of the copper repoussé work were reproduced by local craftsmen. To harmonise the appearance of the new metal elements with the preserved original surfaces, new gilding of the overall surface was necessary. An adhesive based on linseed oil (mixtion) was applied on the surface and Dukaten Doppelgold gold leaf was used for the gilding. Finally, cotton buds soaked in acetone were gently wiped over the surface to create a uniform appearance of the gilded metal (figure 9).

Conservation of the original ivory windows

Some parts of the ivory carvings were dismantled from the wooden beams. Where possible, the iron nails were removed from the carvings. The dismantled carvings were numbered and fixed on Ethafoam plates for further treatment. Very fragile elements were left on the wooden beams. Dust and dirt were removed from the surface with fine, soft brushes. The white coating was removed in

Figure 10 Removal of the white coating with laser.

two steps; mechanically with glass fibre brushes and scalpels, followed by a treatment with a laser. The laser cleaning proved to be very gentle to the porous and fragile surface of the ivory: thick layers of dust and dirt as well as the white coating could be removed easily without damaging the surface of the carvings (figures 10 and 11). The consolidation of fragile and degraded ivory parts was carried out with 10% Paraloid B72 in acetone. The consolidant was applied with a soft brush. Broken ivory parts were joined with 30% Paraloid B72 in acetone. All the treated ivory elements were put back into their original place using brass nails. The loose textile wrapping on the pillars was consolidated with 5% Klucel E in ethanol before the ivory carvings were applied. For safety and easier handling, the wooden parts of the ivory windows were pegged together and fixed on a doubled plywood-board (figure 12).

Reconstruction of the ivory windows

It was suggested by the Kathmandu Valley Preservation Trust that the reconstruction of the precious carvings be done using genuine ivory. Due to ethical and legal reasons, this could not be an option. Several materials for making replicas were selected. Their handling properties were studied and their resistance to environmental conditions was tested by their exposure to UV light.

Because ivory has always been a very precious material a variety of substitute materials and historical recipes for its imitation are available. Most of the historical recipes suggest the use of animal glue and proteins, which is a breeding ground for microbiological growth and for this reason these materials have been excluded. Also, the use of gypsum is not advisable due to its sensitivity to water or humidity and therefore making it unacceptable for exterior use.

There are also several synthetic materials that were used in the nineteenth century to imitate ivory. Probably the most popular substitute was celluloid, invented by J.W. Hyatt in 1863.[29] Celluloid, the first thermoplastic created from cellulose nitrate and camphor, deteriorates quite rapidly; typical signs of its degradation are cracks, crystalline precipitate, fragility, discolouration, shape deformation and a fluid film on the surface.[30]

Ivorina is an early semisynthetic polymer produced from casein. Its characteristic colour striation could give the impression of the lines of Retzius found in ivory.

Another early plastic, bakelite, also named urea bakelite, is a urea formaldehyde resin. For the imitation of ivory it was manufactured into a substance

Figure 11 Surface of the carvings after the laser treatment.

Figure 12 Condition after conservation of the ivory window.

Figure 13 Carved floral pattern, bone.

Figure 14 Carved floral pattern, wood.

Figure 15 Carved floral pattern and leaf decoration, Elforyn.

Figure 16 Carved floral pattern, epoxy resin panels.

Figure 17 Preparation for the casting mould.

Figure 18 Finished moulded reconstruction.

with a high amount of fillers and pigments, such as the mineral barite.[31]

Polyvinyl chloride and polystyrene, both initially synthesised after 1930, were also popular surrogate materials used instead of ivory.

Another substitute for ivory is Elforyn, a high-grade mineral plastic developed and made in Germany. According to the manufacturer Elforyn is a mixture of different minerals, compounded with a light stable resin component that ensures its permanent colour stability.[32] Duhme examined this material in more detail with FTIR spectroscopy. Results show that this material is a kind of polyamide containing different fillers.[33]

The most successful ivory imitations today are made of epoxy resins. Epoxy resins are synthetic reactive prepolymers and polymers which contain epoxide groups. In general, uncured epoxy resins are not mechanically and chemically resistant, therefore their curing is necessary. The curing means the reaction of the linear epoxy resin with suitable curatives, most commonly hardeners, to form three-dimensional highly cross-linked thermoset products with exceptional toughness, adhesion, chemical and ageing resistance. Due to these excellent properties as well as only minimal shrinkage during the hardening process epoxy resins are widely used for different purposes in the conservation of artworks.

Despite their overall stability there are epoxy resins with a weak light stability turning yellow during ageing.[34] For the imitation of ivory light-stable epoxy resins with various fillers and pigments are recommended. The resin can be cast in different moulds.[35] Since the reconstruction with an epoxy resin should be carried out in a reversible way, a layer of Paraloid B72 between the ivory and the cast resin can be used. In case of yellowing the replica can be easily replaced by a new one in the future.[36]

Test series

For the testing of the potential imitation materials, bovine bone, pineapple wood, Elforyn and epoxy resins with different fillers were chosen. All the materials were investigated regarding their workability for carving and they underwent the artificial ageing under UV light. Their stability, regarding the environmental conditions in Nepal and their long-term ageing characteristics, were also examined.

Bone

Bone is chemically similar to ivory, but due to its tubular network it has a relatively rough texture.[37]

To use bones for restoration and as reconstruction material they must first be boiled, dried and be free from marrow. After a drying period of about two weeks, fine plates were cut from boiled bone and prepared for carving. Carvings were made using a fine saw, scalpels and other carving tools. As bone is a very hard material, it was not easy to saw and carve it. Nevertheless, the surface of a carved bone plate was very similar to the carved ivory from the windows (figure 13).

Wood

As there are excellent local craftsmen in Nepal, especially local carvers, the possibility of ivory reconstruction using wood also had to be taken into consideration. From various types of wood, pear wood was selected for testing since it is straight grained and, therefore, suitable for carving.[38] A plate of pear wood was carved and painted with white acrylic paint (figure 14),[39] but its surface appearance did not match that of ivory. Wood grain was visible through the white paint and disturbed the appearance of the surface.

Elforyn

Elforyn is available in different shapes and sizes. For the floral patterns Elforyn panels with a size of 3 x 50 x 305 mm and 5 x 50 x 305 mm were used.[40] Since Elforyn is a soft material suitable for carving, it was easy to saw and to cut it with a scalpel. For the test series, different floral patterns were produced. The appearance of the floral replicas and the workability of Elforyn were good (figure 15), making this material a good choice for using for the reconstruction of the ivory windows.

Epoxy resin with different fillers

Mixtures of epoxy resin[41] with different fillers such as bone powder, marble powder, glass microballoons and white pigments were produced and moulded into panels. Despite the presence of small air bubbles in the cured panels (figure 16), they were suitable for the carving of patterns used for the preparation of casting moulds.

The next step was the preparation of silicone casting moulds from the carved epoxy resin patterns. These were fixed to a wood block with fine nails and a board was fixed around them (figure 17). It was very important that this form board was well sealed, so that the silicone could not leak out. The degassed silicone[42] was then carefully filled into the form and allowed to dry for about 24 hours.

The silicone moulds were ready for making of final replicas in epoxy resin, but this step turned out to be problematic. Due to the presence of fillers like marble powder and bone powder the mould could not be degassed well enough, resulting in a cast with several air bubbles. Therefore, the epoxy resin without any filler, coloured only with white pigment and tinted with a small amount of ochre pigment, was used. The filled moulds had to be degassed for about two hours,[43] and the final casts contained hardly any bubbles (figure 18).

To find the best epoxy resin for the reconstruction of the ivory elements test series were carried out. Three different epoxy resins[44] were artificially aged in a UV-chamber[45] for six weeks. The results showed that colour changes occurred within the first two weeks. After week four no more yellowing was observable. The epoxy resin HXTAL NYL showed only slight yellowing after six weeks of exposure. Despite the outstanding UV stability of the HXTAL NYL epoxy resin it could not be used in situ due to its long curing time of up to seven days. Therefore, an epoxy resin Epotek 301-2 with only one day hardening time was chosen, despite its UV stability not being as good as that of the HXTAL NYL resin. Epotek 301-2 pigmented with zinc white and yellow ochre was selected as the best option.

Conclusion

These test series can be considered as preliminary studies for the reconstruction of the ivory elements. The reconstruction of the windows and their ivory décor was carried out by colleagues of the Institute of Conservation, University of Applied Arts Vienna, during the conservation campaigns between 2014 and 2016.[46] The replicas were reinstalled at the façade of Sundari Chowk in Summer 2016. The central metal window has been put back to its former position on the palace façade between the reconstructions.

The original ivory windows were fully conserved and are exhibited at the Patan Museum under stable climatic conditions. Recommendations were made for their storage and exhibition, with regard to the climatic conditions in Nepal. This new stable environment will help to protect the original ivory windows from further decay which was caused by the fluctuating climate, sunlight and air pollution of its former position on the façade.

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Notes

[1] Project leadership: Univ. Prof. Dr. Phil. Mag. Art. Gabriela Krist, Funding: Austrian Development Agency (ADA), Office of the Federal Chancellor, Ministry of Foreign Affairs Local partner: Kathmandu Valley Preservation Trust (KVPT), Eurasia Pacific Uninet (EPU).

[2] UNESCO, Master Plan for the Conservation of the Cultural Heritage in the Kathmandu Valley, Paris 1981, p. 9; In 1979, the World Heritage Committee approved Nepal's application to place seven sites in the Kathmandu Valley on the World Heritage List. The seven sites that have been chosen are representative of all aspects of Nepal's Cultural Heritage, its architecture, art and religion. The Seven Monuments of the Kathmandu Valley are: The Kathmandu Durbar Square, the Patan Durbar Square, the Bhaktapur Durbar Square, the Buddhist Stupa of Swayambhunath and Boddanath, the Hindus temple complex of Changu Narayan and Pashupatinath.

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[20] Jehle 1995, pp. 334-347.

[21] Freund 1999, p. 14.

[22] Freund 1999, p. 3.

[23] Freund 1999, p. 16.

[24] Freund 1999, pp. 17-21.

[25] Freund 1999, p. 52.

[26] Analysis by SEM-EDX were carried out by Prof. Dipl.-Ing. Rudolf Erlach, Archaeometry Department, Institute for Art and Technology, University of Applied Arts Vienna.

[27] Zinc white was commercially available since the middle of the nineteenth century.

[28] A glass fibre transmitted Nd-YAG laser, Eos 1000 LQS, from El.En. Company (Italy) was used.

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[40] Purchased by Bachman Kunststoff Technologien GmbH.

[41] EPO-TEK 301-2 purchased by Kremer Pigmente.

[42] Wacker Silicones, Elastosil 4470, purchased by Kurt & Wolf CO KG.

[43] Information by Mr. Manfred Trummer – MAK, Vienna 23.04.2013.
[44] ARALDIT 2020, Epotek 301-2, HXTAL NYL.
[45] HERA EUS Typ 6030, Heroeus Instruments
[46] Manfred Trummer, Museum of Applied Arts Vienna. Marina Paric, 'The Ivory windows of the Sundary Chowk at the Royal Palace in Patan, Nepal. Conservation and Reconstruction', Diploma Thesis at the University of Applied Arts Vienna, Vienna 2017.