MÁRCIA DANTAS BRAGA
Rio de Janeiro, Brazil
marcia@marciabraga.arq.br

THE CONSERVATION OF THE STATUE OF *CHRIST THE REDEEMER*, RIO DE JANEIRO, 2010

Keywords: mosaic restoration, federal heritage, laboratory analyses, outdoor sculpture

ABSTRACT

The conservation carried out in 2010 on the Rio de Janeiro's iconic *Christ the Redeemer* statue included on-site condition assessment, laboratory analyses of the stone, identification of microbiological species, and artificial aging tests of a water repellent. The following procedures were performed: removal of graffiti, cleaning, opening and filling of cracks, replacement of tesserae, re-grouting and application of a water repellent.

RÉSUMÉ

La conservation en 2010 de la statue iconique du *Christ Rédempteur* de Rio de Janeiro a inclus l'évaluation de son état *in situ*, des analyses de la pierre en laboratoire, l'identification des espèces microbiologiques en présence et des essais de vieillissement artificiel d'un agent hydrofuge. Les procédures suivantes ont été entreprises : enlèvement des graffiti, nettoyage, écartement et comblement des fissures, remplacement des tesselles, remasticage et application d'un agent hydrofuge.

RESUMEN

Las labores de conservación de la icónica estatua de Río de Janeiro, el Cristo Redentor, realizadas en 2010, incluyeron un estudio *in situ* del estado de conservación, análisis de laboratorio de la piedra, la identificación de las especies microbiológicas y pruebas de envejecimiento artificial de un material hidrofugante. Se llevaron a cabo los siguientes procedimientos: eliminación del graffiti, limpieza, limpieza y resane de las grietas, sustitución de teselas, consolidación con lechadas y morteros y la aplicación de un material hidrofugante.

INTRODUCTION

The statue of *Christ the Redeemer* is composed of a reinforced concrete structure supporting the cast concrete sections that give the monument its form. This concrete casing is clad in a soapstone (steatite) mosaic with triangular tesserae approximately 4 cm in length and 5 mm thick. The work was designed and executed by the Brazilian engineer Heitor da Silva Costa and was completed in 1931. The principal co-authors were Oswald, the artist who designed the statue; Caquot, the engineer who carried out the structural calculations; Landowski, the artist who built the head and the hands; and Levy, a craftsman.

The figure is 30 m high and its arms measure 28 m from fingertip to fingertip. It is mounted on an eight-meter-high pedestal. A mortar made from very fine aggregate was used both for the setting bed of the mosaic and for the grout between the tesserae. This mortar is approximately 0.5 to 1.0 cm thick and overlays the coarser layer of the concrete casing (12 cm thick).

The statue has five large covered apertures through which people can pass. One of these openings is located on top of the head and the four others, in the shoulders and elbows. There are 14 smaller openings: ten are positioned vertically in the sides of the body, two at the front at chest-height and two opposite them at the back. When open, they assist with the circulation of air and the internal lighting of the statue.

The monument was declared municipal heritage in 1990 and federal heritage in 2009. It is the private property of the Archiepiscopal Miter of Rio de Janeiro. The author was responsible for designing the 2010 restoration project and for its technical execution. Cone Engenharia was the company in charge of supplying the materials, labor and management.

PREVIOUS INTERVENTIONS

The monument has undergone large-scale interventions every 10 years since 1980. There are reports that the statue was cleaned in 1980. This process may have been repeated in 1990, followed by the application of a silane/siloxane manufactured by Wacker. In 2000, a further cleaning of the monument was carried out using low-pressure water jets. Additionally, tesserae that suffered problems from internal discontinuity of the layers of

mortar were replaced. It is possible to identify two types of replacement tesserae, some more bluish and others of more varied coloration, tending to yellow and brown. The dissimilarity of the mortar used for re-grouting in the previous interventions also assisted in its identification, due to its different porosity and coloration.

ASSESSMENT OF THE STATE OF PRESERVATION

The pathologies identified and mapped in this intervention were: salts, cracking, stains, biological growth, superficial loss of grout, exfoliation of the stone, non-original tesserae, missing tesserae, loss of mortar from the mosaic setting base and visible rust.

Laboratory analyses conducted on new and original tesserae demonstrated that the principal processes of the monument's deterioration are caused by weathering. The investigations carried out by the Minerals Studies Technology Center (CETEM) include evaluation of color and gloss, chemical composition and mineralogy of the stone, determination of the physical indices of water absorption and vapor permeability, ultrasonic wave propagation, uniaxial compressive strength, three point flexural tests, thermal behavior and tests of the state of the water repellent. As a consequence of exposure to the exterior environment, the porosity of the stone had increased and the grout showed surface wear. Cracks were usually located over the concrete structure. The majority of these cracks are in places where there was already some prior intervention. Opening them confirmed that they were superficial.

The Atlantic rainforest is responsible for spores associated with microbiological colonization, according to identification analyses carried out by the Mattos e Mattos Laboratory. The micro-organisms found were: *Penicillium* sp., *Fusarium* sp., *Cladosporium* sp., *Aspergillus* sp., *Ascoliquen* and heterotrophic bacteria.

The unreliable grounding of the lightning protection system allowed atmospheric discharges to strike the statue's more prominent extremities, such as the top of the head, the eyebrows and the tips of the fingers, causing losses and exposing the metal elements in the concrete casing. In the second half of 2009, work was carried out on the monument including a study of the efficiency of the lightning protection.

The interventions carried out previously typically present tesserae and mortar that are different from the original. The mortar of these interventions was finer. These areas absorb less water than the original surface, which results in the accumulation of water in the areas around them. These interventions were also considered detrimental to the aesthetics of the monument.

With regard to the mapping of the state of the interior of the statue, it should be noted that what can be seen today is not the original interior surface of the concrete casing. A cathodic protection system was installed in 2000. It consists in part of a metallic array that was applied over the entire interior surface and then covered with mortar. This mortar exhibits

various stains apparently caused by the drying of water. A comparison between the location of the external cracks and these internal stains showed that there was no relationship between them.

Another factor that contributed to water accumulating on the inside of the statue was the obstruction of the gullies in the lower parts of the arms.

The petrographic and microbiological laboratory analyses confirmed the aforementioned wear, which was fundamental to the approval of the restoration methodologies proposed to the work's inspection team.

Figure 1
The figure surrounded by scaffolding

Figure 2
Graffiti on the face

CONSERVATION PROCEDURES

Erection of scaffolding

The erection of the scaffolding was initiated in February 2010 by the company Rohr. This time the operation included the construction of a stair tower up to the height of the shoulders and the placement of work platforms around fifty percent of the statue. It was completed in five weeks (Figure 1).

Removal of graffiti

The monument was closed for a six-day period when heavy rains caused barriers in the Tijuca National Park to break. During this time, vandals were able to reach the monument and leave graffiti all over the face, chest, and the front part of the right arm. (Figure 2) All the graffiti was photographically documented and then covered with cement laitance to preserve the dignity of the monument until further measures could be taken. The stages for the removal of the graffiti followed the sequence described below:

- dry removal of the cement laitance using plastic bristle brushes and oakum;
- localized application of a paste stripper over the black spray paint by paintbrush with light friction. The principal active ingredients of the stripper are: methylene chloride, methyl alcohol and ammonium hydroxide, in a mixture of cellulose ether and paraffin esters;
- removal of the paste stripper after approximately five minutes with dry cotton, taking care not to spread the paint;
- application of mineral spirit more broadly over the vandalized surface using cotton swabs. This dilutes the stripper impregnated with the graffiti ink, facilitating the mechanical removal of the residue;
- cleaning of the surface with a ten percent solution of neutral detergent. This ensures the more complete removal of the graffiti and facilitates the repetition of the process in areas where traces remain;
- rinsing using plastic bristle brushes.

The procedures were repeated in specific locations. The key element in their success was the immediacy of the response.

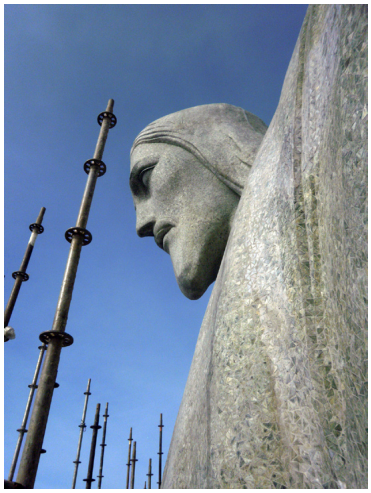
Cleaning

The cleaning of the statue was carried out with steam and water at approximately 70º Celsius. Kärcher supplied the equipment and the personnel who operated the equipment (Figure 3).

The pressure of the model DE 4002 device was calibrated to remain between three and four bars. The steam or water jet was delivered through the head of a nylon brush rubbed against the surface. The cleaning was carefully carried out in order to remove the biological patina from the tesserae and grout. The areas where the moisture accumulated, such as under the chin and the arms, and in the south and west sides which are exposed to storm winds, displayed marked superficial deterioration, thus indicating the chemical action of fungi in the production of acids.

The plan for the restoration of the figure included other cleaning agents. However, following a request from the Brazilian Environmental Institute (IBAMA), it was opted to carry out the work using just water and vapor, since the aesthetic result achieved with the steam and water was deemed comparable to those places where some kind of biocide was used.

The cleaning process was executed in two stages; the second followed the re-grouting to remove remaining material from the tesserae. The cleaning was responsible for a notable brightening of the statue.



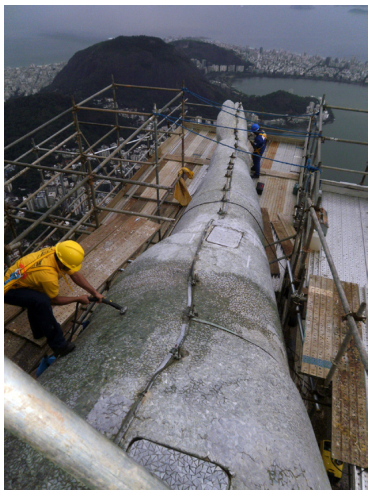


Figure 3
Cleaning of the right arm

Figure 4
Opening of a crack in the side of the head

Opening of cracks and removal of tesserae

Following the cleaning, it was possible to characterize in further detail the cracks that had been previously identified. These cracks were no greater than three millimeters wide and were opened using small electric shaft drills with heads two and half millimeters in diameter and small chisels. The depth proved to be no greater than one centimeter. The removal of the cracked tesserae was also carried out using the same methodology. This resulted in a minimum substitution of pieces (Figure 4).

Treatment of the exposed metalwork

Portions of the metal reinforcing structure of the concrete casing were exposed, primarily at the top of the head and the tips of the fingers. The rust was removed from the surface using small metal brushes, in preparation for the application of a primer with anti-rust treatment.

Replacement of the mortar

Prior to replacement of the mortar, samples of the two types were collected: that used for the grout and setting bed of the tesserae and that of the concrete casing. The analyses were carried out by the Technological Centre for Preservation and Restoration (NTPR) and provided composition indicators for the aggregates and binder, granulometry for the inert substances and coloration for the whole. The results of the analysis showed mortars rich in cement and sand. The proportions found were

1:1 for the mortar used for the setting bed and grout and 3:7 for the concrete casing mortar.

The entire surface of the statue was superficially worn, including both the exposed grout and the exfoliated tesserae. The grout exhibited general wear, as well as erosion of its finer components. The mortar selected to replace the missing grout and setting bed had slightly coarser grains than that identified in the sample analysis. Some factors made it desirable to make this adaptation, rather than attempting to precisely duplicate the laboratory results.

Although the original bedding mortar and grout are composed of essentially the same materials, the grout which remains exposed suffers from a process of deterioration different from that of the setting bed. Mortars with more varied grain size are more resistant because they require a smaller quantity of binder. It seemed possible to restore the monument with respect for its current state of preservation while also introducing a product of greater durability.

Figure 5
Replacing of tesserae

The complete re-grouting of the statue would add some residue to the tesserae. Using coarser mortar would avoid filling micro-cracks in the tesserae.

Replacement of the tesserae

The replacement tesserae were used primarily over cracks, in the missing areas located in the top of the head, on the tips of the fingers and in the sample collection sites. (Figure 5) The principal difficulty in this replacement process concerned the use of tesserae of the same color as the originals.

The original tesserae possess a light green tone and this color of soapstone is increasingly difficult to find in the natural world. The process of deterioration has turned some minerals of the steatite rock (soapstone) a lighter tone. The statue also possesses original tesserae with chromatic variations in smaller quantities.

Up to 2010, replacement tesserae were intentionally different in hue from the originals. This was due to a request from the National Historic Heritage Institute (IPHAN). However, the initiative did not produce a harmonious aesthetic result. The issue was reviewed during this intervention and it was decided that the replacements should not be easily identifiable by visitors, but clearly recognizable when viewed from scaffolding during future interventions.

The selection of the tesserae to be used was carefully undertaken. Approximately eighty percent of the replacement tesserae was discarded in order to achieve satisfactory chromatic adjustment. It is estimated that less than 5% of the original tesserae was replaced. The new tesserae came from the same region as the originals, in the state of Minas Gerais. Some discussions took place regarding the additions to old interventions, which were of a different color than the original. In these areas it was decided to use

new tesserae that were close in tone to the earlier replacements surrounding them in order to avoid further disruption or chromatic discontinuity.

Re-grouting

Once the tasks of cleaning, treatment of the cracks and the exposed metalwork and the replacement of the mortar and tesserae had been completed, the re-grouting of the entire surface was carried out in order to treat the whole surface, which had deteriorated to different degrees. There is no reference to this work ever having been executed before on the monument. In the tests carried out prior to the intervention, an application of a silane/siloxane was made before the re-grouting. This sequence of procedures was shown not to increase the adhesion of the regrouting, as the area lost was less than 2 mm thick.

The entire re-grouting was carried out by applying the grout with a plastic spatula and soon after removing the excess with wet sponges. In addition to its purpose of preserving the monument, it achieved aesthetic homogeneity of the surface (Figure 6). It is important to note that this procedure left residues on the tesserae (principally the most worn ones) and that it caused a lightening of the surface. This lightening was much less than that observed following the cleaning and the removal of the microorganisms. The grout is an element that suffers continual wear, generally greater than that of the tesserae. Its existence can be considered temporary, like that of the waterproofing material used subsequently. Its application does not represent a permanent intervention like that of the replacement of the tesserae. The method of applying the grout over the entire surface and removing the excess almost immediately was the best option we could come up with in the circumstances.

Figure 6
During re-grouting

Figure 7
The chest and face after conservation

Application of the water repellent

The suitability of the use of a vapor-permeable water-proofing resin on the exterior surface of the statue was the subject of scientific studies in order to obtain approval for its use by the monument's inspection authority.

Thirty-six samples of tesserae were collected from the four sides for analysis of their state of conservation and for artificial aging tests. These analyses carried out by CETEM resulted in the recommendation of the application of the product due to a reduction in water absorption of approximately 80 per cent.

For the artificial aging analyses, Silres BS290 (a silane/siloxane manufactured by Wacker) was applied in two coats to the new and original tesserae in a 10 per cent solution, in accordance with the manufacturer's recommendations. The measurements indicated a superficial darkening, according to the chromatic parameters of the laboratory equipment.

When this water repellent was applied to the monument in the 10 per cent solution, it resulted in an undesirable darkening. Tests were conducted with the application of two coats of the 5 per cent solution – a percentage commonly

used in applications on porous surfaces (stone, mortar, ceramics, etc.) – and the aesthetic result was acceptable, producing only a subtle darkening.

The dilution of the repellent does not mean that it would be more effective if used in a higher concentration. As the rock's capillaries are very narrow, the greater the dilution, the greater its penetration. Its efficiency could be verified soon after some rainfall, which demonstrated the water droplet effect on the surface of the statue.

The location of the test application of the silane/siloxane in the 10 per cent solution (over half the cover of the right shoulder) is identified in the documentation, for monitoring purposes.

Figure 8
The statue after conservation, June 2010

Treatment of the interior

Operations performed inside the statue comprised the following:

- general cleaning
- clearing of the gullies
- treatment of the exposed metalwork of the support structure and concrete casing
- repair of the cathodic system
- restoration of the ventilation covers
- repair of the stairway
- installation of permanent lighting.

CONCLUSIONS

The restoration of the *Christ the Redeemer* statue was based on a project submitted to IPHAN. Technicians from this institute contributed to the specification of the necessary laboratory analyses, in addition to supervising the execution of the entire project. The project's specifications were all confirmed by the laboratory analysis. We would like these studies not to conclude with this stage, but through the continuation of this research, to support subsequent interventions by providing scientific data to ensure the longer-lasting and safer preservation of the monument.

Although elements of surprise are common in restoration projects, in this case only the vandalism required emergency procedures.

Main conclusions of the scientific analyses

The original tesserae have a darker tone than the replacement tesserae from the years 2000 and 2010, which is explained by wear due to various environmental factors and possibly to the intrinsic qualities of the composition of the rock.

The process of hidrofugation/water-proofing was responsible for the reduction in the levels of porosity and the capacity to absorb water of

the tesserae and grout. This reduction was more marked in the original tesserae, reaching 90 percent.

The levels of specific, dry and saturated mass of the original tesserae are lower than those commonly found in the literature on soap stone, but were found in the tesserae of 2000 and 2010. This fact may be due to the high degree of wear of the tesserae sampled from the monument.

As regards the mineralogical characterization, the original tesserae display greater diversity of minerals (tremolite, actynolite and chlorite) than the later ones, indicating materials of different metamorphic facies.

The results of the chemical analysis indicated little variation between all the tesserae, with high levels of magnesium and silicon observed. The impact of saline mist was responsible for the change in the tonality of the pieces, both naturally and hidrofugated, possibly indicating that the action of the sea air on the statue is one of the elements responsible for the darkening and lightening of different areas of the mosaic.

Following the attacks of humidity and saline mist, it was observed that the hidrofugate/water-proofer was resistant to this accelerated test.

The low levels of thermal dilation observed prove that the material is highly resistant to abrupt variations in temperature.

REFERENCES

AIRES-BARROS, L. 2001. *As rochas dos monumentos portugueses – tipologias e patologias*. Lisboa: Instituto Português do Património Arquitectónico/Ministério da Cultura.

BRAGA, M. 2003. *Conservação e restauro – pedra, pintura mural e pintura sobre tela*. Rio de Janeiro: Editora Rio.

CANEVA, G., M.P. NUGARI, and O. SALVADORI. 1991. *Biology in conservation of works of art*. Rome: ICCROM.

KÜHL, B.M. 2009. *Preservação do patrimônio arquitetônico da industrialização – problemas teóricos de restauro*. São Paulo: Ateliê Editorial/Fapesp.

MUÑOZ VIÑAS, S. 2003. *Teoria contemporánea de la restauración*. Madrid: Sintesis.

OLIVEIRA, M.M. 2002. *Tecnologia da conservação e da restauração – materiais e estruturas*. Salvador: Edufba.

MATERIALS LIST

SILRES BS290 (silane/siloxane)
Wacker

Paste stripper (methylene chloride, methyl alcohol, ammonium hydroxide, cellulose ether and paraffin esters)
Vanda

Mineral spirit
Vetec

Neutral detergent (neutron spectrum)
Detertec

Water and vapor jet device model DE 4002 (Pressure 3 to 4 Bars, temperature 70°C)
Kärcher

Small electric shaft drill
Dremmel

PCF (primer anti-rust)
Quimatic