Conservation and Restoration of the Don José I Monument in Lisbon, Portugal. Part I: Stone Components

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Abstract

The equestrian statue of D. José I, in Lisbon, Portugal, stands on an elegant and decorated plinth fashioned in a very dense limestone. The sculptor, Joaquim Machado de Castro, designed the pedestal with colossal stone pieces and selected one of the best Portuguese stones for this purpose, the Lioz limestone. The same stone was also used for the flanking sculpture groups and the base This stone is a very pure reef limestone, rich in fossils and a low porosity <1%. It is extremely compact and highly resistant, even in the harsh environment of a busy metropolis and within the impact of marine winds. The generalized deterioration is surface erosion caused by direct runoff water, with some incipient black crusts and soiling incrustations occurring in sheltered places. In some areas copper stains originating from the metal statue were also found. An extensive network of cracks was found, mostly at or near the top of the plinth, which could be ascribed to the presence of iron rods and clamps left inside the structure to hold the stone pieces together. During the intervention, these cracks were sealed with a multi-barrier system, given the impossibility to access the interior to remove or directly passivate the iron inclusions. Inoperative joints were cleaned out and repointed. Black deposits could be eliminated by nebulized water and soft brushing while the copper stains required the application of poultices with ammonium carbonate, in some cases requiring the addition of a complexing agent.

Keywords: D. José I statue; stone plinth; stone sculptures; Lioz limestone; conservation

1. Introduction

The equestrian statue of Don José I is located in the center of the Commerce Square (Praça do Comércio), which was created on the former Palace yard after the 1755 earthquake that destroyed the center of Lisbon. King Joseph I (1750-1777), the Reformer, appointed Sebastião José de Carvalho e Melo, Marquis of Pombal, as his Prime Minister, and it was he who planned and organized the reconstruction of downtown Lisbon after the devastating earthquake. To honor the King, the Marquis of Pombal decided to have the monument erected in this location and called for a competition of design proposals. The one submitted by Joaquim Machado de Castro (1731-1822), an equestrian statue cast in metal, set upon a high stone base, was selected in 1770 [1]. The monument was inaugurated in June 1775, on the 61st birthday of the Don José I.

The elliptical base is lined with large thick panels of Lioz limestone and adorned with three sculpted groups: Royal Generosity on the north side, Fame on the east, and Triumph on the west. On the south side there is a medallion in a copper alloy with the bust of the Marquis of Pombal, and above it, carved in stone, the royal shield. In 1910 it was listed as a National Monument. The monument is a major landmark of downtown Lisbon and it was intentionally located facing the Tagus river before it reaches the sea to serve as a welcoming gesture to visitors. It is considered as the masterpiece of Joaquim Machado de Castro and an iconic symbol of Lisbon.

Early in the 21st century, the general appearance of the monument and its state of conservation were unsatisfactory so that authorities decided to undertake a thorough maintenance campaign to mitigate the deterioration phenomena while improving its overall condition For this purpose, a collaboration protocol between Lisbon Municipality (CML) and World Monuments Fund Portugal (WMF-P) was established, and an extensive intervention was planned and prepared in 2008, and finally implemented from August 2012 to July 2013.

This paper addresses the conservation of the stone elements: the base and the carved sculpture groups, while the following paper considers the cast metal sculpture. Both papers address the basic steps to be respected both in terms of identification of deterioration problems, the evaluation of the most appropriate conservation actions, and the solutions actually applied to the monument.

2. Condition of the Monument

The main sculpture – the cast metal statue of King D. José I – is placed over a massive masonry plinth using colossal stone pieces perfectly assembled to support the 38 ton metal sculpture. The plinth shaft has only four 4 pieces, each of them weighing some 25 tons or more (Figure 1). The stone used in the monument is a very dense limestone (Lioz stone) quarried in the Lisbon region [2,3,4], and extensively used in the reconstruction of Lisbon post-earthquake.

Figure 1. North view of the plinth and the adjacent sculptured groups before the intervention. The bas-relief depicts the allegory "Royal Generosity".

The Lioz stone is very compact, its porosity falling around or below 1% [5,6], and characterized by the high percentage of fossils included. The sculptor managed to select one of the best varieties of this sedimentary rock, which is reflected today in the very good conservation state of the stone surfaces. The extreme compactness of this stone turns it resistant to most decay agents, the solubility of calcite – its major and almost exclusive constituent – being its weakest factor. Its location in an urban environment where anthropogenic air pollution turns rain water more acidic results in an increased dissolution of the stone surface. Air pollution was monitored over several years both in the urban region of Lisbon and across the river in the industrial area of Barreiro. Table 1 gives these values and shows a significant decrease in SO_2 pollution in the last 4 years measured as industrial air pollution was being reduced [7].

Table 1. Average deposition rate (mg/m^2.day) values for SO_2 and chlorides in the urban area of Lisbon, and the industrial area of Barreiro across the river from Lisbon from 1985-1993 [7]. (Note:* indicates that the average for the first 4 years (1985-198) was around 200 mg/m^2.d, while in the subsequent years (1990-1993) the average value was reduced to around 50 mg/m^2.d) .

Species measured	Lisbon	Barreiro
SO_2	14 (mg/m^2.d)	136*(mg/m^2.d)
Cl^-	7 (mg/m^2.d)	38 (mg/m^2.d)

Differences in the crystal sizes of calcite in the Lioz limestone lead to different solubility rates, fossils—being denser than the overall limestone— as well as the scarce quartz grains will protrude from the surface as the stone is slowly dissolved giving it a rough texture along the paths that rain water follow down the monument. Figure 2 displays some characteristic aspects of this differential erosion pattern. Since most areas are directly exposed to rain water, any soiling from air pollution is washed away. However, sheltered areas developed black gypsum crusts, some of them forming thick and spongy deposits (Figure 3 right). The crusts were mainly constituted by gypsum with traces of halite (NaCl) resulting from the proximity of the Tagus river (see Table 1). They mainly represented an aesthetic problem, the impact being limited to the stone surface given the very low porosity of the high quality Lioz limestone used, and no in-depth deterioration, such as flaking or powdering, was observed. Some greenish stripes were also found on the upper part of the pedestal as a result of the washing down of copper ions from the metal sculpture. Figure 3 displays some aspects of the black crusts and copper green stripes.

Figure 2. Differential erosion caused by the acidic run off waters (left). Fossil remains and some silica grains stay in relief on the stone surface (right).

Figure 3. Aspects of the sheltered areas where black crusts are formed and the deposition of copper ions originated green staining (left). Black gypsum crusts developed thick deposits in the most protected areas (right).

The most striking features affecting the stone elements were the fractures detected in the horizontal cover and uppermost slabs of the plinth (Figure 4). These fractures have a long history, as the past repairs, clearly suggest. Documents of such interventions were not found, but the incisions on the horseshoe indicate that at least in 1922 and 1983 major interventions were made (Figure 5).

Some of the major fractures had clean borders, suggesting that they are still evolving. In a few places, these fractures could be correlated to iron rods left inside the masonry to connect the different stone slabs. To clarify the possible origin of these fractures, a geo-radar evaluation was carried out by the Minho University [8] (Figure 6).

Figure 4. Details of the top and upper part of the plinth showing some fractures. Some of them were stabilised with bronze rivets during previous interventions (left). Detail of the fracturing pattern (right).

Figure 5. Incisions made in ~~Detail of~~ the horseshoe of the statue indicating ~~incisions stating~~ the date when ~~that~~ interventions were made ~~in (~~1922 and 1983~~) were made~~.

Figure 6. Survey with geo-radar in the upper part (left) and top of the plinth (right).

The survey detected several reflection signals (Figure 7) that could be ascribed to metal rods located between blocks, very likely serving as connecting elements to stabilize the overall plinth structure. This finding was fundamental for the condition assessment, since the fractures could be reasonably attributed to the corrosion of these rods, and served to define the type of mitigation actions to be applied.

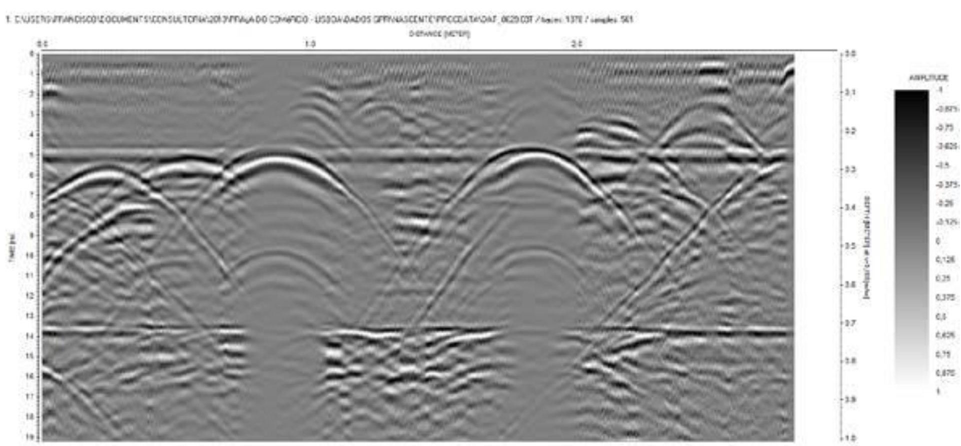

Figure 7. Example of a radargraph. The hyperboles are echoes from the connecting iron rods inside the plinth [8].

3. Conservation implementation

The fractures present in the plinth constituted the most serious conservation issue. However, once their origin was identified, the necessary procedures to address them could be defined. A definitive solution, such as the extraction of the iron rods, or their passivation, could not be readily implemented since being deep within the plinth they are totally inaccessible. The only option was to seal the fractures with multiple barriers of mortar interposed with flexible polyurethane cord to prevent water seepage into the plinth's interior (Figure 8) [8]. While not the perfect solution, this approach will limit the amount of water penetration; however, it requires on-going periodic monitoring to ensure the good condition of the sealing so that immediate action can be taken as the first sign of deterioration.

Figure 8. Aspect of the top of the plinth showing the fractures sealed and the visible bronze clamps treated.

Cleaning and repointing of deteriorated joints was carried out systematically on the entire pedestal, base and including the surrounding steps. Defective joints between blocks were removed and all open joints were cleaned out to assure good bonding with the new mortars. For larger openings, a more resistant hydraulic mortar or injection grout was used, while for thin joints, a similar mortar was used but with ~~ensuring that the aggregate~~ was smaller grain size and matching the average color ~~grain size~~ of the stone ~~was used~~.

The main conservation intervention required was the cleaning of the black crusts and the copper stains, previously mentioned. The overall black crusts were removed by water nebulization sprayed over it to slowly dissolve away the accumulated gypsum thus washing out the black air pollution trapped in it. For localized, harder deposits, a micro-abrasion approach was used. The copper stains were eliminated by applying cellulose poultices with ammonium carbonate.~~, and~~ ~~i~~In areas where they were not completely removed, 2% tetra sodium EDTA was added to the poultices which were controlled regularly to check their effectiveness and to avoid damaging the substrate. EDTA (ethylene diamine tetraacetic acid) is a complexing agent that has been used extensively in its disodium form at pH 8.5 to remove gypsum crusts, since it complexes calcium ions (Ca^{++}) among many others such as copper (Cu^{++}). At this pH, the acid may also solubilize some of the calcite, but gypsum being about 100 times more soluble, it preferentially complexes the Ca^{++} from this salt. As a tetrasodium salt (pH ~11) no significant dissolution of the calcite is expected while copper ions will be complexed preferentially since the Cu-EDTA complex is nearly twice as stable as that for calcium (K_{st} 18.8 and 10.7 respectively). In view of the high quality and low porosity of the Lioz limestone no consolidation was necessary nor application of a protective coating [9]. A view of the monument after the complete intervention is shown in Figure 9.

Figure 9. North view of the monument after total completion of the conservation intervention.

4. Discussion and Conclusions

The condition assessment revealed that the various fractures found in the upper part of the plinth were the most critical problem affecting the stone elements of the monument. An initial working hypothesis was that they originated from localized unbalanced loads from the heavy metallic structure, with a possible contribution from seismic activity. Although this hypothesis couldn't be discarded with full certainty, a few direct observations suggested that the main fractures could have resulted from the corrosion of iron elements existing within the plinth. The survey with geo-radar made laterally and from the top of the pedestal allowed to determine the position of several echo sources where large stone slabs were in contact with each other. These could be attributed to iron elements to serving to clamp the blocks so as to strengthen the transverse resistance of the plinth. This is a traditional approach and in this instance they were fully justified given the slenderness of the plinth and the large dimensions of the stone slabs. But their location precluded a direct access to treat or to replace them and an alternative solution had to be considered. Moisture migration through the stone slabs is minimal, given the extreme compactness of the Lioz limestone, therefore the main access could only occur via joints and fractures. Under these circumstances, an effective solution to prevent water ingress was developed based on a system of multiple barriers. This was implemented, by alternating compacted mortar layers intercalated with elastic polyurethane cord. With all the detected fractures duly treated, the access of water to the iron rods will be reduced to a minimum, thus limiting any further corrosion of the rods. To work properly as a long term protection, careful routinely inspections are necessary and eventual remediation measures implemented as a maintenance work at any first signs of water seepage.

Comparatively, cleaning actions were within a normal degree of complexity, given the high quality of the stone substrate. Undecorated areas could be cleaned with nebulised water and soft brushing and only in a few places poulticing was necessary to eliminate more stubborn green copper stains.

In conclusion, the implemented conservation actions were relatively moderate and all the work could be carried out without major difficulties. A proper identification of problems and the comprehension of deterioration processes allowed the correct selection of required conservation actions. Last, but not least, the execution by a professional team of conservator-restorers contributed significantly to the present condition of this unique monument.

Acknowledgments

The conservation project of this monument was made possible by the support from World Monuments Fund Portugal, WMF through the Robert Wilson Challenge Fund, the Câmara Municipal de Lisboa and some private donors. The authors thank Prof. L. Aires Barros for his participation in the discussions during the evaluation of the project and its implementation. Nuno Proença and the team of Nova Conservação Lda. are acknowledged for their willingness to share detailed information on the various interventions carried out. The radargraph in Figure 7 was adapted from the report of Minho University.

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