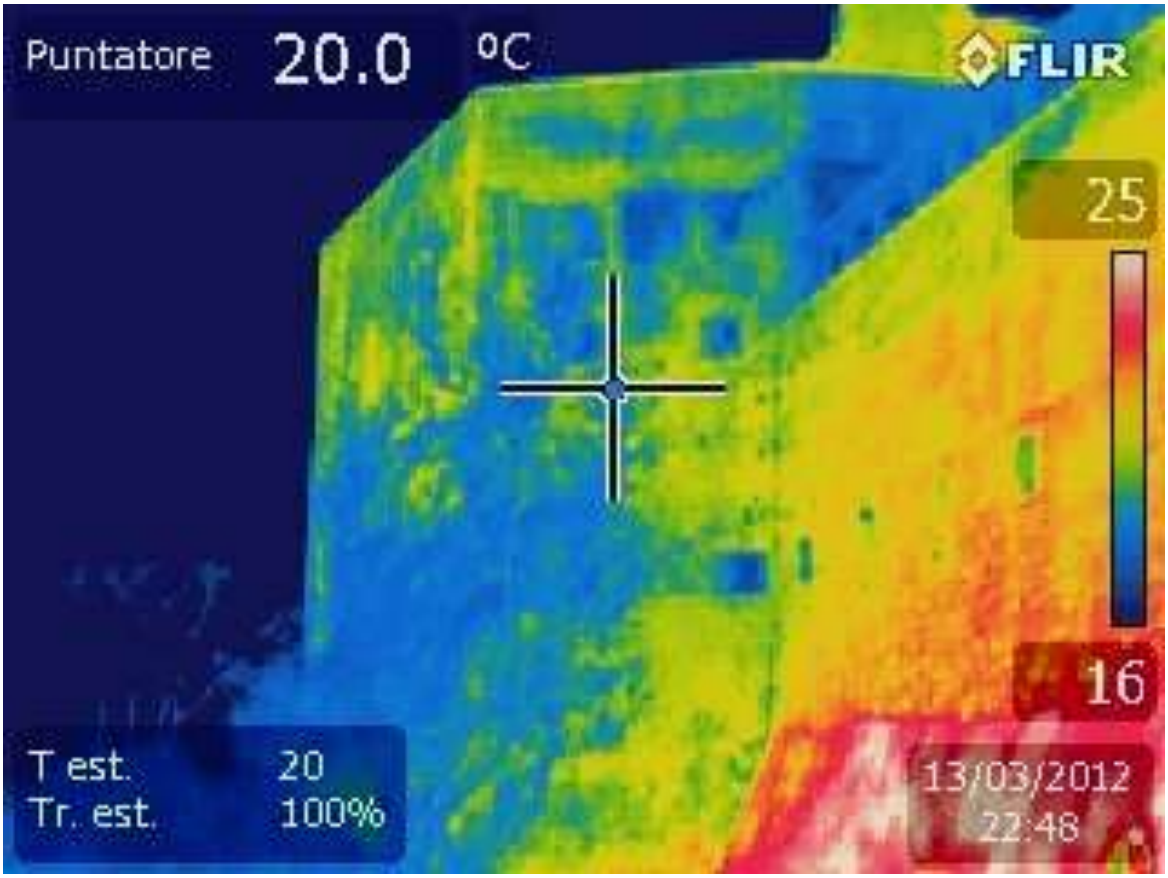
Evaluation of the State of Conservation of the Site inscribed in 1982 on the World Heritage List as "National Historic Park – Citadel, Sans Souci, Ramiers" Criteria (iv), (vi).

Mission Report of the Survey

6-22 March 2012



April 2012

United Nations
Educational, Scientific and
Cultural Organization

World Heritage Convention

GOBIERNO DE ESPAÑA MINISTERIO DE CULTURA
FONDOS EXTRAPRESUPUESTARIOS ESPAÑOLES

Contents

Purposes of the Mission

According to the contract for services N° 4500169029 of 2 March 2012, the activities to be carried out during the mission were:

1. Identify technical experts and establish a multidisciplinary team of 5 to 6 experts to undertake the tasks identified below, in line with the specific requirements of the World Heritage property concerned;

2. Organize a 2 week mission to Haiti, in March 2012, including at least 10 days at the National History Park - Citadel, Sans Souci, Ramiers, based on a mission programme developed in close coordination with the World Heritage Centre;

3. Conduct an in-depth analysis of the state of conservation of the World Heritage property with a particular focus on the Citadel, the Sans Souci Palace and the monuments at Ramiers, taking into account prior conservation measures and the impact of the January 2010 earthquake. This includes taking samples for further in-depth analysis of materials and evaluating the structural conditions of the most damaged fortified components.;

4. Identify comprehensive conservation measures in order to allow for the long-term preservation of the property, with clear indication of priority measures, and prepare technical specifications and budgets;

5. Collaborate with ISPAN staff, and involve them in the conservation measures and regular maintenance requirements for the different monuments. Prepare together with ISPAN the requirements for maintenance and conservation for the key construction materials, the impact of environmental agents, and the structural condition of the main buildings.

As for the requirements of point 1), the group of experts was composed as follows:

1. Costantino Meucci, Chemical expert in conservation (University of Rome "La Sapienza"), team leader,
2. Antonella Altieri, Biologist of ISCR (Istituto Superiore Conservazione e Restauro) Rome,
3. Stefano Marini, Geologist and Restorer, ("Atelier Morisse-Marini, *Restauration et Conservation d'oeuvres d'art* ") France,
4. Stefano Ridolfi, Physics expert in Non Destructive Analyses (University of Rome "La Sapienza"),
5. Maria Letizia Conforto, Architect (University of Rome "Tor Vergata"), who was unable to participate in this mission due to health problems requiring urgent medical treatment.

The mission was technically coordinated by Nuria Sanz, Chief of the Latin America and Caribbean Unit of the UNESCO World Heritage Centre.

According to the specific requirements of point 2), the mission lasted from 6-22 March with a continued stay of 11 days at the National History Park (9-19 March) in order to develop the activities listed in point 3). During this period, specific conservation measures were identified in cooperation with the ISPAN experts in order to guarantee the best conservation of the monuments and acting as soon as possible to ensure the stability of unsafe buildings (in particular the Coidavid Battery and the Queen and Princess Batteries) and to

coordinate the execution of the conservation plan, as agreed with the experts during the survey.

A short training session was also carried out aiming to introduce some of the young ISPAN young members to the methodologies to be used to document the state of degradation of the monuments. A total of 8 people participated in the Sans Souci analysis, while only three participated in the Citadel documentation and only one (namely the architect Théodore Perari, who was the coordinator of the ISPAN members) participated in the Ramiers analysis as well.

During the field work, several analytical Non Destructive (ND) investigations were implemented such as XRF Analysis of the guns, IR Thermography of the walls, determination of the water content both of the masonry and of the wooden gun carriages and measurement of the light impacting the walls with biological patinas. The sampling of the original materials and of the degradation patterns was also taken in order to determine the composition of the masonry, the technology used to produce the quicklime and the bricks as well as identifying and isolating the degradation mechanisms affecting all materials.

Field training session at Sans Souci Royal Palac.

Planning of the Activities

In agreement with the UNESCO World Heritage Centre and ISPAN, the planning of the field activities was developed according to the following timetable:

	Mer	Jed	Ven	Sam	Dim	Lun	Mar	Mer	Jed	Ven	Sam	Dim	Lun	Mar	Mer
Activité	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
Arrivée à Port-Au-Prince															
Transfert Port-au-Princ - Cap Haitien															
SANS SOUCI															
1. Individuation des zones de référence															
2. Fichage des dommages typiques dans les zones de référence															
4. Échantillonnage biologique															
5. Documentation photographique des zones de référence															
CITADELLE															
1. Fichage des dommages typiques dans la Citadelle, notamment du Bastion Coidavid et de la Batterie de la Reine															
2. Échantillonnage des maçonneries: mortiers et briques															
3. Échantillonnage biologique															
4. Assemblement d'une station de surveillance du microclimat et des sollicitations mécaniques des maçonneries fissurées															
5. Documentation photographique des zones de référence															
RAMIERS et FOUR À CHAUX															
1. Individuation du bâtiment de référence															
2. Fichage du bâtiment de référence															
3. Échantillonnage des maçonneries (mortiers et briques) et des matériaux cuites dans le four à chaux															
4. Échantillonnage biologique															
5. Documentation photographique des zones de référence															
Départ pour Port-au-Prince															
Meeting at the UNESCO Office															
Meeting with Carmen Rodríguez Coordinadora General Oficina técnica de Cooperación Española (AECID), Embajada de España															
Meeting avec les responsables de ISPAN															
Départ pour Paris															

Field Activity

The field activities were developed according to the above working plan and were finalized to answer the peculiar task of the long term conservation of the monuments included in the National History Park. In this section all observations made on each monument will be summarized to define the best conservation solutions both in the short and long term.

Sans Souci Palace: Analysis and conservation needs of the site

The site displayed several conservation problems that needed to be analyzed separately in order to define the best restoration solution for each monument. Although the buildings constituting Sans Souci demonstrate different states of conservation, many of them may be considered as archaeological ruins because of the impacts they have suffered in the last two hundred years. For instance, the Queen Palace is the best preserved of the buildings, however the degradation it shows is so high that all restoration interventions cannot take into account the building reconstruction, which will entail changing the external look of the remains. However, the height of the walls and the lack both of the intermediate floor and of the roof impose the rehabilitation of part of the building to avoid that it collapses definitively. The general criterion to be followed is that there must be a minimal intervention in order to preserve both the look of the monument and the general image of the site. Thus, all monuments must be treated with the same methodologies applied to the conservation of the archaeological areas: cutting and removing of rotting plants, structural consolidation of the parts in danger of collapse using both direct and indirect solutions, cleaning of the surfaces and restoration of the original plaster, and finally capping the top of the walls by using suitable hydrophobic mortars particularly studied for the conservation of the archaeological areas[1].

Sans Souci - the remains of the Queen Palace

Comparing the look of the wall remains at the South side of the site which verifies that the restoration recently carried out aims to rebuild portions of the buildings in order to implement their structural continuity, but also to increase the visibility of the entire planimetry of the site. Nevertheless, although the philosophical restoration is correct, the reconstruction interventions might be considered too extensive and invasive and not recognized as conservation intervention, according to the generally accepted idea of conservation.

[1] The results of the laboratory research and of the practical intervention recently carried out in Italy are reported in: C. Meucci & I. Nicolini, *Malte idrorepellenti per il restauro archeologico. Il caso della villa di Tor Caldara ad Anzio (Roma)*, *Boll. ICR Nuova Serie*, 14, 2007, pp.34-52.

Sans Souci; comparison of the lookof the wall remains before (left) and after (right) the restoration.

Furthermore, the choice of the restoration materials may not be adequate and this may apply to the rebuilding methodologies as some recent damage on the restored walls demonstrates.

The damage is also due to the lack of ordinary maintenance that is necessary in order to prevent plants from growing within the masonry causing the restoration plaster fissure to detach so that the degradation rate increases.

The sensation that this kind of restoration generates is that the reconstruction of the perimetrical wall of the King Garden and of the surrounding houses does not result from a general intervention project, but from the contingent necessity to stop the degradation of the existing remains. On the contrary, the recent discussions with Mr Henry Jolibois confirm the necessity to prepare a restoration project that considers both the conservation of the wall remains and the reconstruction of the garden as in the original plan. This look will be further discussed with the support of a botanist, based on the results of the archaeological excavation to be planned and carried out at the site.

Sans Souci - damages to the recently restored wall.

Sans Souci: analysis and conservation of the Royal Palace

The Royal Palace or Great Palace is the building that is the primary focus of attention for conservators both because of its historical value and the complexity of its restoration. Observing the monument confirms that the building is characterized by very poor structural stability due to the height of the walls and the lack of floors connecting the vertical structures at each level. Thus, the only solution to be adopted to assure the conservation of the Palace consists in the reconstruction of the intermediate levels in order to increase the cohesiveness of the entire structure. Indeed, the presence of floors and roofing is the only solution to preventing rainwater from penetrating the masonry and causing damage that currently affects

the monument. However, the reconstruction must be projected with a conservative criterion without affecting both the originality of the building and its appearance. The first survey of the monument allowed the isolation of the peculiar necessities to be covered in order to assure the conservation of the building: the structural interventions to preliminarily assure the stability of the building, the rehabilitation of the water drainage system aiming to prevent water stagnation under the structures, and finally the conservation interventions on the walls to stop the degradation of the plaster and the masonry.

Sans Souci Great Palace: view of the main facade from the North side.

Structural interventions

Observing the monument allows isolating many fissures located at the highest part of the walls and in the arches that may drastically affect the stability of the building. The entire building must be analyzed in detail in order to properly record by drawings the structural damages affecting the walls prior to any restoration intervention. The use of the quick photogrammetry, which is based on the instrumental analysis of the recorded images, will help to obtain in a very short time the distribution of the fissures and of the loss of masonry with reference to each single building unit. This will become the base for the projecting of the local interventions aiming to increase the mechanical resistance of the structure. Monitoring the fissures for a long time, by using strain gauges and data loggers, will also give information on the movements of the masonry which is fundamental to properly project the structural restoration. During the survey, the arch connecting the throne room with the South entrance of the Palace was investigated in order to assess how solar radiation could affect the width of the fissure.

Sans Souci - fissures at the top of the walls may affect the stability of the building.

Sans Souci - monitoring the fissure of the arch by a strain gauge connected with a data logger.

Due to the short measurement time, no movements were recorded by the instrument, however the experiment confirmed the necessity of long-term continuous monitoring.

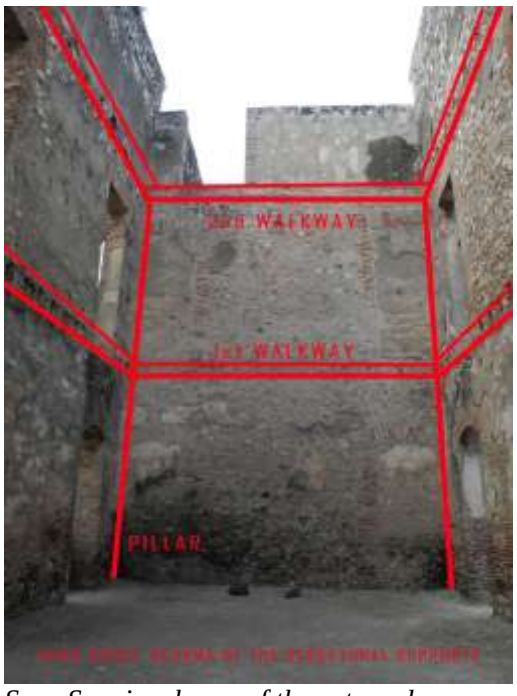
The intervention must be carried out in separate steps, as follows:

1) Making a photogrammetric mapping of the building will allow the possibility of studying the fissuring distribution and of creating a reference mathematical model which will be useful to project structural intervention.

2) Erecting inside each room, scaffolding in order to mechanically support the walls and to allow punctual recording of the state of degradation of the masonry. This is a temporary solution which is absolutely necessary to acquire all the relevant data to define the restoration project. Once the scaffolding is built, the structural monitoring will start by using no more than 10 strain gauges connected with individualized data loggers, located in correspondence to the critical fissures, while three accelerometers will be located at the top of the most critical and solicited vertical walls to check the tilting induced by the wind and the mechanical stresses. The contemporary documentation of the degradation will be done. The presence of the scaffolding is also necessary to allow the execution of the restoration works, once defined by the project.

3) Applying the mathematical modeling of the building to study the efficacy of the structural supports and the resistance of the restored building to the impacts of earthquakes. The modeling is also necessary to define size, chemical composition and physical characteristics of the external supports of the vertical walls.

4) Increasing the stability of the structures means restoring the building because of the impossibility to stabilize the vertical wall without inserting external elements that may mechanically support the walls. Discussions with Mr Mangonès allowed hypothesizing about the use of pillars made of carbon fibers and epoxy located in the corners of the rooms and connected by a horizontal beam made of the same materials at the original first floor level. The aerial circumambulatory made of light and resistant grids (the industrial roofing made of epoxy might be used) will increase the mechanical resistance of the supporting structure and make it possible to visit. The perimetrical structure is 20-30 cm detached from the original wall, but directly connected to this by inserting suitable carbon fiber elements into the holes where the beams supporting the pavement were originally located. The second level might be consolidated with the same technique, while the upper third floor will be consolidated by vertical triangularly shaped elements connected by resistant dralon lines treated with epoxy resin. The suggested solution derives from the experience made in the archaeological site of



Sans Souci; schema of the external structural supports.

Herculaneum[2], where a supporting shell made of carbon fiber and epoxy resin was specifically projected, to resist earthquake tremors. However, the structure must be exactly calculated on the base of the mathematical modeling of the building, properly stressed in order to simulate the earthquake shocks.

Water drainage assessment

Part of the survey was finalized to isolate the causes of the damages induced by the presence of the water in/on the walls of the Palace. The field measurements were made by using the IR Thermography camera, which allows recording both the traditional and the IR image, and by a portable water-meter that gives the percentage water content of the masonry.

Sans Souci - water content determination

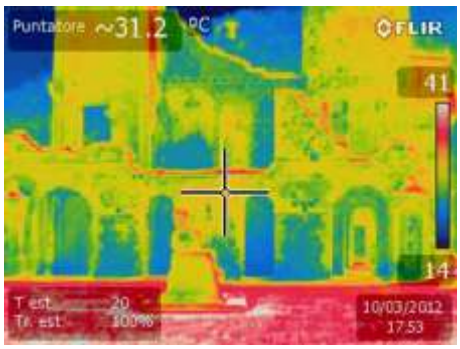
Sans Souci - water distribution measurement by IR Thermography camera

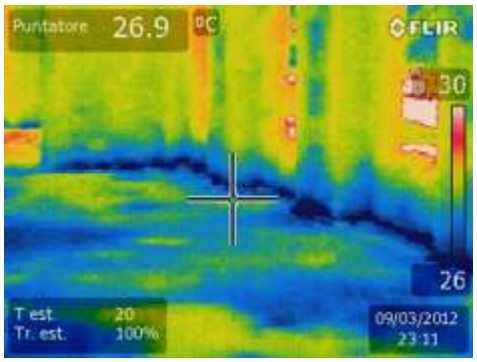
The water content of the masonry varies according to the height of the measurement and the location, and with the nature of the masonry as well. Close to the pavement the percentage is highest and decreases with the height, while it is reduced in the plaster, however in the mortar it does not exceed the value of 4%. The measurements confirm that the source of water is located behind the pavement and that this is most likely due to the dispersion in the soil of the spring water that originally fed the fountains.

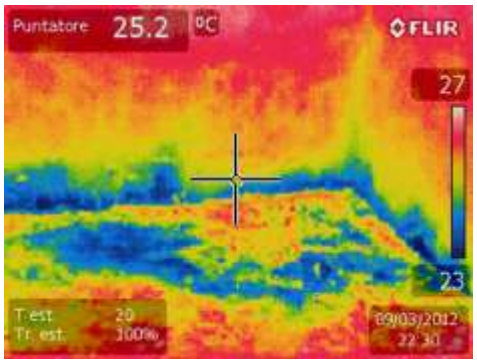
The IR thermography, on the contrary, gives more precise information because of the possibility to record the traditional and the IR images, as well as the value of the temperature. The proposed image sequence illustrates how the water comes from the West esplanade reaching the external walls of the Palace through the original canals (currently obstructed) and the natural absorption in the soil. When the foundation of the wall is reached, the capillary causes the raising of water into the masonry according to its size, shape and nature, however the concentration in the pavement is also favored.

[2] Refer to: C. Meucci, M. Pagano, A. Bertocchi, R. Cami, A. Procaccio, M. Indirli, M. Forni, P. Clemente, A. PacielloH. Ahmadi, K. Fuller, *The use of an Innovative 3D-Isolation System for Seismic and Ambient Vibration to Protect the Roman Ship Excavated at Ercolano, Proceedings of the 7th International Seminar on Seismic Isolation, Passive Energy Dissipation and Active Control of Vibration of Structures*, Assisi, Italy, October 2-5, 2001.

In the case of the North-West rooms of the Palace, the presence of water in the pavement induces the differential absorption in the wall and in the pillar, but also in the corners when the wall is linear.





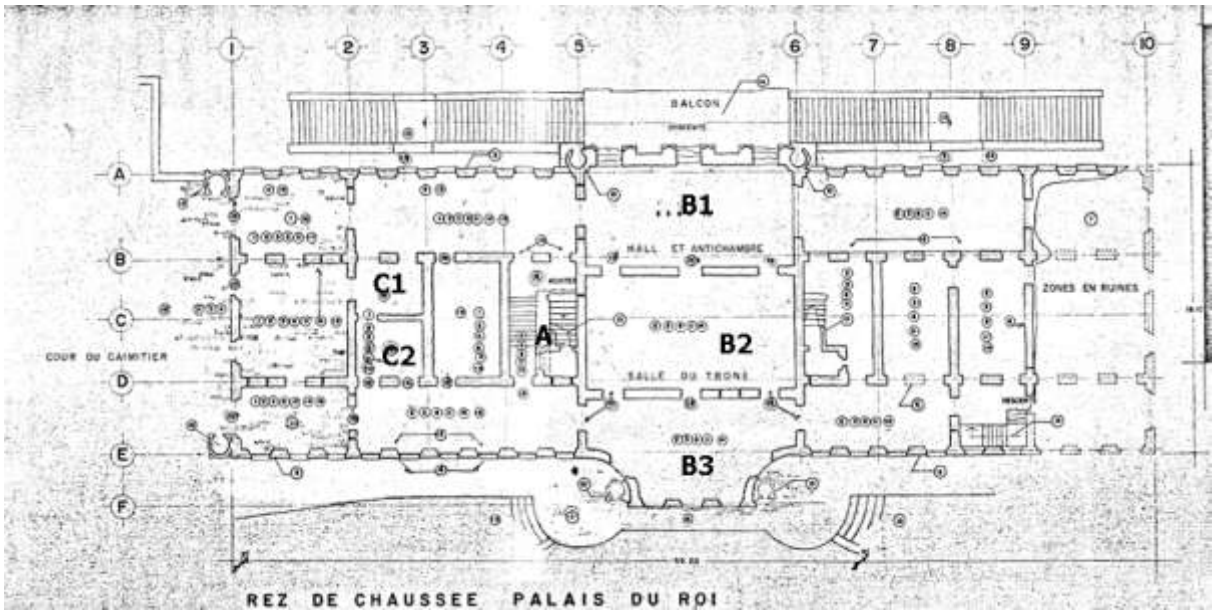


Sans Souci - the sequence of the IR thermographies clearly shows that the water concentrates in the pavement ascending by capillary into the walls.

Drying the foundation is necessary in order to reduce the damage caused by the capillary and represents the first step of the structural intervention. Although the hypothesized project contemplates the excavation of the pavements and the collection of the rainwater in the middle of the room by flooring it in the suitable way and creating a new canal system to drain the water, the respect of the original structures and hydraulic system imposes the rehabilitation of the original drainage system and the collection of the rainwater and the underground water out of the building. Thus, the excavation must be executed by archaeologists in order to isolate the original building phase which refers to the project's restoration.

Restoration interventions

In order to isolate the most suitable restoration procedures and to define the conservation project, the central section of the Royal Palace has been analyzed from several points of view that allow characterizing the degradation mechanisms and the related typical damage. The survey involved the entire group of experts and a limited number of local people from ISPAN that were trained as for the recording of the several degradation patterns to be observed in the monument.



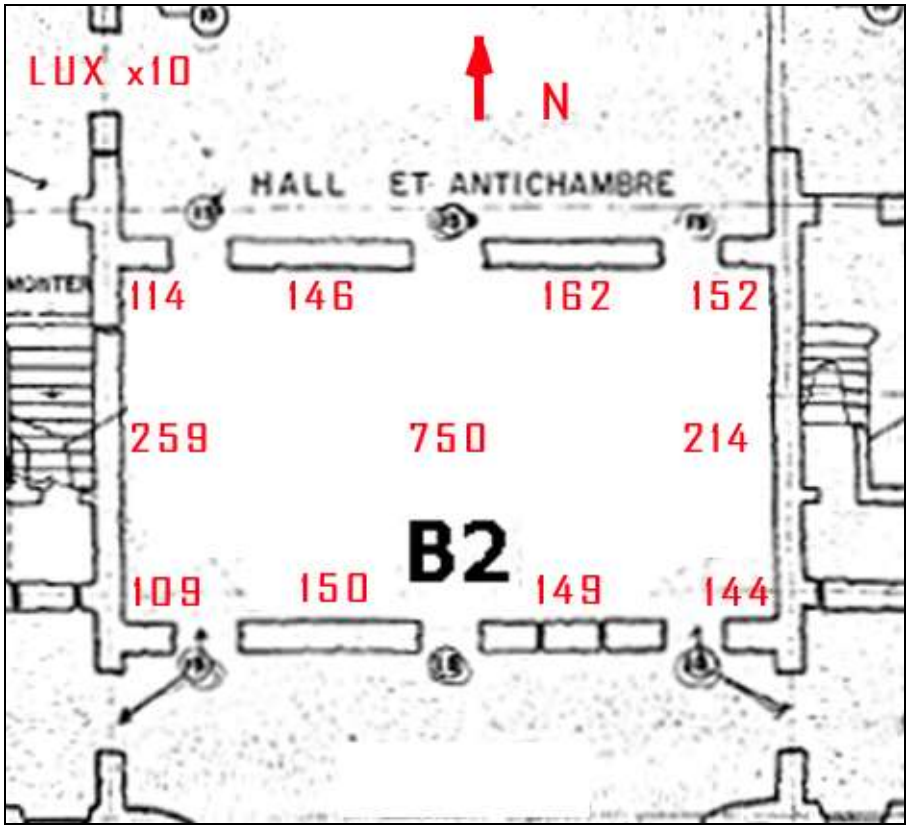
The reference rooms were conventionally called A, B and C; this contains C1 and C2 units.

The factors that mainly cause the degradation of the structure were isolated into the biological patinas that affect all wet surfaces; indeed, micro and macro-organisms like sub aerial algae, fungi, lichens, mosses and higher plants were macroscopically visible on the architecture surfaces.

The biological patinas are massively present in all wet areas, as IR thermography confirmed, but also the impacting light affects their growth.

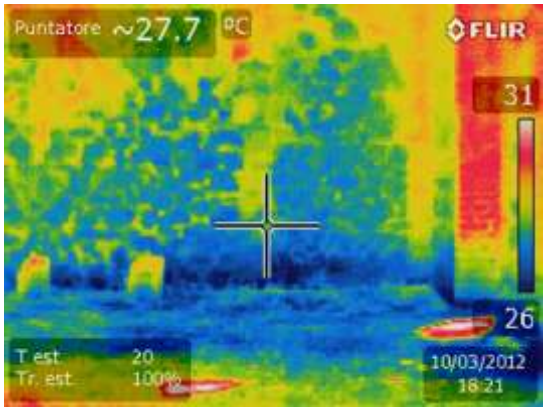
Sans Souci - IR Thermography and Light measurements in correspondence to the biological patinas.

Measuring at the height of 185cm the light intensity on several walls of room B2 (corresponding to the Throne Room) at 3:00 PM confirms that the height of the walls reduces the intensity of the impacting light three to six times the environment value, according to the exposure of the wall. The biological patinas develop according to their exposure to the sun, as well as the chemical degradation of the materials composing the masonry.



Representing the distribution of the original plaster remains and of the biological patinas, as well as the restoration intervention on the reference wall is a mean to evaluate both the impact of the degradation on the original masonry and the intervention procedures. In the B2 West wall, for instance, the red areas indicate that the restoration of the remains of the original plaster will be extended to about 30% of the surface, while the biological attack also involves the restored wall. The distribution of the biological patinas correspond to the areas where water is present both because of the capillary from the soil and due to the rainwater penetration through the top of the wall. Extending this kind of analysis to all walls result in exactly projecting the restoration in terms of procedures, materials and costs. In the Sans Souci Royal Palace, the great problem is the presence of water in all pavements, which results in capillary

affecting the wall for several meters according to the materials composing the masonry and the degradation they suffer. As for the restoration methodology to be applied to stop the capillary, we consider that the cutting of the base of the wall is ineffective and will also introduce a further cause of damage owing to the decreasing of the mechanical resistance.



Sans Souci - capillary causes that water retained by the pavement raises several meters into the masonry as the East wall of the B2 room proves. The blue areas are the areas most wet.

The conservative restoration of the Palace will be focused on the restoration of the walls, with peculiar attention to the cleaning and the consolidation of plasters and masonry, but also to the capping of the top of the walls. In order to precisely describe the degradation mechanisms and to identify the most useful materials and methodologies for the restoration, many biological degradation patinas and both plaster and mural painting samples were taken to carry out peculiar analyses; brick and stone samples were collected as well to characterize the production technology and the provenance of the building materials.

The cleaning of the surfaces will take into account the predominant presence of biological patinas that affect the wet surfaces. Aiming to assess the efficacy of the most common biocides, cleaning tests were performed in room B2 (the green patina on the plaster with light brown color at the bottom of the South wall, and the black patina affecting the bottom of the West wall close to the Southern corner) using Preventol 4% v/v.

Green patina before and after 7 day treatment

Black patina before and after 7 day treatment

The results obtained in the short time of the mission confirm the efficacy of the commonly applied commercial products and make it possible for defining the restoration project as regards to the biological cleaning.

Some areas frequently show deep degradation of the bricks, probably due to the continuous presence of water and wind, which increases the evaporation rate of water. The visible degradation patterns, consisting in the powdering and scaling of the bricks and of the binding mortar, impose to strengthen the degraded materials by using both inorganic traditional materials and organic suitable chemicals generally allied for the conservation of degraded stones.

The conservative restoration will aim to increase the consistency of the original materials and to reduce the degradation rate to the minimum value so that the structural intervention may be carried out. The activities to be carried out are as follows.

1) Increasing the stability of plasters and mortars by the intrusion of suitable hydraulic liquid mortars and plastering of the boundaries with aerial mortar made of lime and sand;
2) Cleaning of the surfaces affected by biological patinas both by spraying biocides in suitable concentration and applying cellulose packs saturated with the biocide;
3) Chemical cleaning of the surfaces affected by salt deposition, efflorescence and incrustation by using ammonium hydro-carbonate solutions in suitable concentration applied by pack;
4) Mechanical removal of cement mortars eventually applied during the previous restoration works and causing degradation of the masonry;
5) Locally strengthening, by using suitable chemicals of the several materials (stone, mortar, plaster, brick and metal) that need treatment, according to the necessities ascertained during the cleaning interventions;
6) Filling of the grouting and missing parts of the plasters and masonry with suitable mortar, according to the composition and the function of the masonry.

Citadel: analysis and conservation of the site

Due to its complexity, the monument presents several conservation problems that may be related to three main causes: the seismic events that generate structural diseases of the buildings; the presence of water inside the masonry both coming from the rain and from the soil; and the lack of maintenance. The sum of these external factors has caused the decay of the several batteries composing the site; however, the degradation develops according to the peculiar geometry of the building, the technology used for the building, the nature of the original composing materials, and the exposure to the environment. The restoration interventions and the nature of the materials used to rehabilitate the monument may also play a fundamental role in the degradation processes.

In order to achieve a general view of the problems and the priorities for the conservation of the monument, the state of degradation of the most visited batteries will be discussed separately with the aim to individuate the best restoration methodologies.

Coidavid Battery

The survey of the external surfaces of both the Coidavid and its basement confirms the presence of angularly shaped fissures starting from the loophole of the first level because of the collapse of the roof (which is the horizontal resistant element) due to the mechanical stresses of the earthquake. Similar fissures are visible from the inside of the building as the survey of the ground floor of the battery shows. The lower two levels of Coidavid Battery are in fact collapsed reducing the mechanical resistance of the entire structure. Studying the distribution of the fissures will help in the diagnosis of the static of the building, allowing the precise definition of the criteria and the methodologies to be applied to properly restore the building. Referring to this philosophy, the monitoring system actually working in the third level of the battery aims to verify the stability of the building structure taking into account one of the most heavily fissured gun window of the Battery, namely the third of the North side.

Coidavid Battery - Fissuring on the floor of the 3rd level due to the earthquake stresses

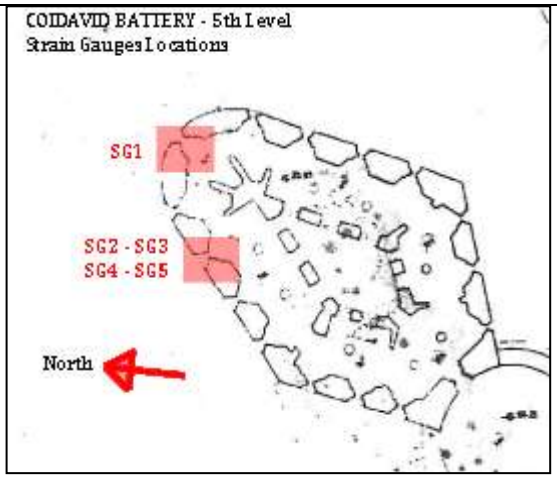
Aiming to assess the stability of the building one strain gauge connected to a data logger was applied on two separate days to record the movements of the largest external fissure cutting transversally the base. The system should be in place for three days in order to

continuously record the values of temperature, relative humidity and width of the fissure in order to make it possible to verify if the movement of the fissure was cyclic or not, and consequently projecting the monitoring system. Unfortunately, the system was disturbed the first day, however the data recorded two days before in the same location allowed the confirmation that the fissure width increased by 0.020 mm with a non-cyclic movement.

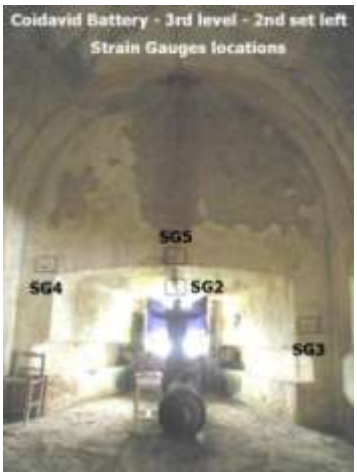
	
Spur - observing the fissures in the wall	*Spur - preparing the monitoring system*
	
Spur - verifying the functioning of the system	*Spur - the monitoring system is working*

With the same strategy, several strain gauges were located at the 3rd level of the battery across some of the visible fissures according to the location of the map.

The SG1 tool is located on the floor and aims to record the movements of the fissure cutting the pavement from the gun window to the large hole that opens in the floor in the extreme corner of the Coidavid, in the same direction of the spur.



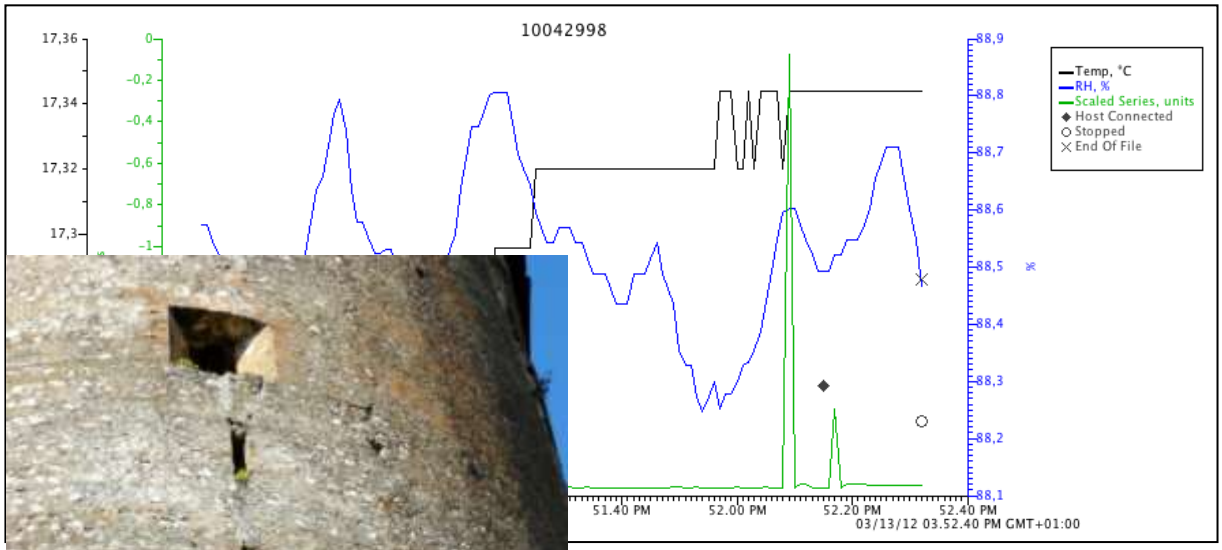
Coidavid; location of the monitoring system



Coidavid; location of the strain gauges

The second set on the left side of the Battery shows a very complex fissuring model with a vertical fissure starting from the top smog aperture above the window, while two other cracks open transversally from the base of the vault to the base of the wall; the figure shows the locations of the strain gauges. The opposite side of the set, which opens on the inner court, is affected by a crack that transversally intersects the right wall starting from the middle vault and reaching the base of the window. However, this fissure seems due to the karstic activity that markedly affected the vault and the walls starting from the overlaying pavement.

After 24 hours, all probes have been tested in order to verify the efficacy of the system. The strain gauge series work well and show interesting data in the SG1 location, owing to the variations recorded in the fissure size. A dynamic test was then carried out in order to verify the range of the movement and the location of the maximum solicitation.

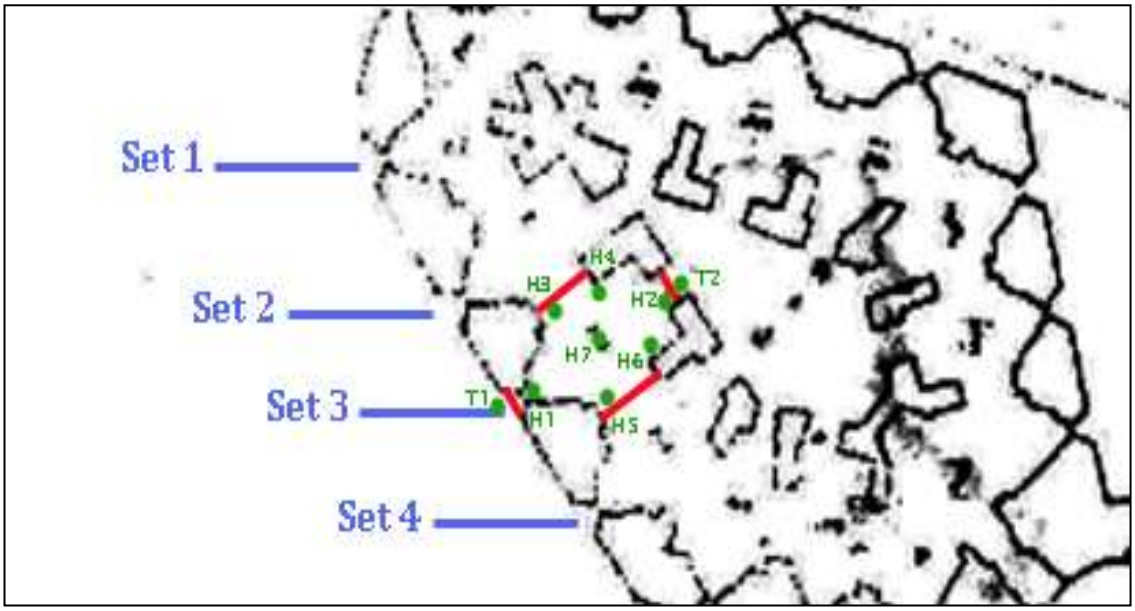


The data recorded confirms that the highest solicitation is located between the corner of the Coidavid (where the fissure starts) and the opposite wall, immediately after the big hole due to the vault collapse. Observing the green

line allows identifying that each mechanical solicitation applied to the roof 2.5 meters fare from the hole by jumping on it (the force applied is valuable to 1,000 Newton) causes an enlargement of the fissure by about 0.020 mm; on the contrary, the jumping close to the hole causes the fissure enlargement to reach 2 mm, while the solicitation applied on the left side of the fissure causes it to open 0.200 mm only. This preliminary test proves that the corner of the Coidavid is affected by very severe mechanical solicitations, which may cause the collapse of the structure if the elastic limit value of the masonry is reached.

The microclimate monitoring system has been assembled in the Coidavid 3rd level, 3rd set left side and planned to start acquisition on 13 March 13 at 12:00 AM. The probes were located according to the following schema.

H1-T1 = external temperature and indoor T/RU/Text North
H2-T2 = external temperature and indoor T/RU/Text South
H3 = T/RU/Text
H4 = T/RU/Text
H5 = T/RU/Text
H6 = T/RU/Text
H7 = T/RU/LUX reference indoor average

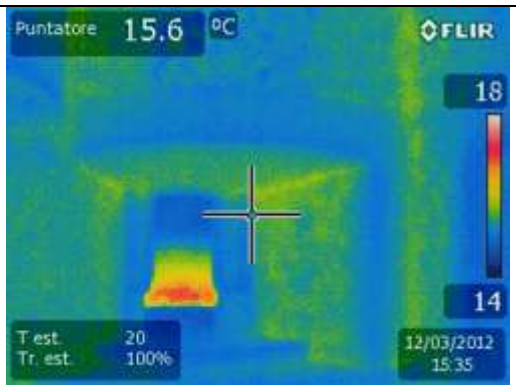


All probes were properly located to avoid that humidity affects the precision of the measures and the validity of the monitoring itself.

After 24 hours, all microclimate probes have been tested in order to verify the efficacy of the system: H1-T1 probe only needed to be re-launched to correctly record the external reference data. Comparing the data recorded during the first week allows verifying that the external temperature on the North face is higher than in the internal court.

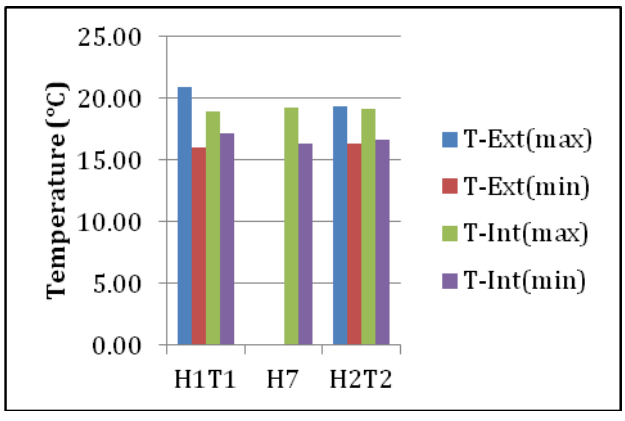
Also the internal temperature values of the North probe (H1T1) are the highest, while the probe located in the center of the set recorded values very similar to those of the H2T2 probe, which is located close to the internal court of the Coidavid. The same trend shows the Relative Humidity, which reaches the saturation value (100%) both in the North location and in the H7 probe located in the center of the room as average environment reference probe, while the minimum average value is about 79.50%. Although these data refer to a very limited acquisition time, their variations seem to be significant and useful to characterize the behavior of the environment in the several condition of use. The 3rd set was in fact partly isolated from the rest of the level by applying wooden and plastic frames closing the transversal passage and transparent glasses that close the windows, simulating the exhibition layout.

The 3rd level of Coidavid was also analyzed by IR thermography in order to individuate the anomalies due to the water presence: the origin of the seepage waters has been ascertained confirming that the penetration of water occurs mainly from the roof. Indeed, the vault of the 4th set right side appeared water saturated, while the walls were warm and dry. This may explain the degradation mechanism and also indicates that it is active at the moment.



Coidavid; IR thermograph shows that the flat arches are wet, as well as the external walls

The same 3rd level of the battery has been investigated for the biological degradation that affects the wall surfaces. Sampling of the main degradation patterns was made as well. The masonry was also investigated in order to assess its compositional anomalies or peculiarities, and to identify the best locations from which to take significant samples. Biological cleaning tests were also performed in several areas in order to verify the efficacy of the cleaning solution on the different degradation patterns.

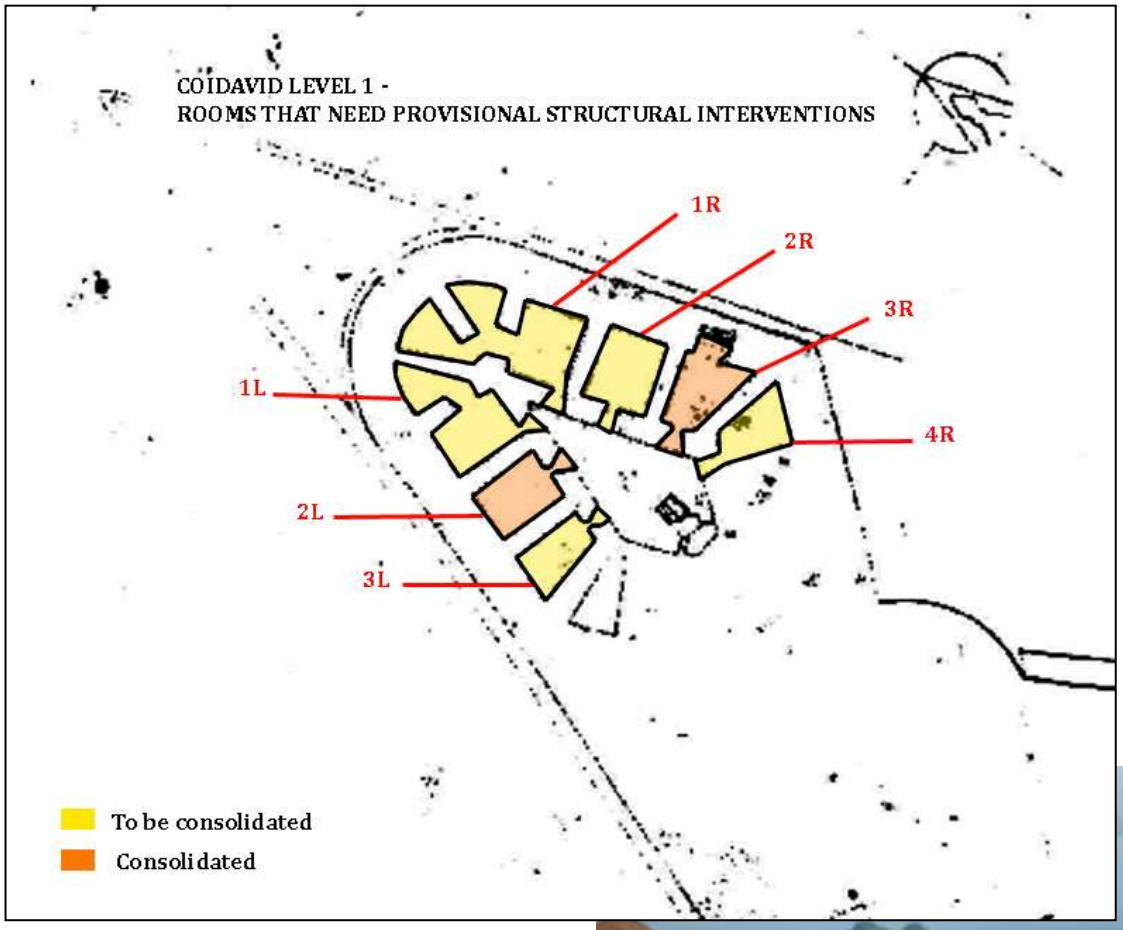


The survey to the upper level of Coidavid resulted very important to verify the good state of conservation of the dry masonries and the efficacy of the provisional roofing by metallic sheets. Nevertheless in some areas the roofing must be optimized, the solution adopted

to protect the building results working properly. The IR thermographs recorded in some areas showed that the temperature of the metallic roof is always about four degrees higher than that of the masonry; this implies the necessity to isolate the roof by applying a false ceiling made of gypsum foils (such as the Placo-Plâtre isolating panels) or wooden panels. Removing from that level all extraneous materials and those stored will make it possible to use the space as show room or museum of the most interesting and precious artillery pieces (the guns and mortars made of bronze actually stored in the Officer Quarter rooms and the small bronze culverin stored in the Grand Boucan dormitory).

Restoration interventions

The risk of total collapse of the Coidavid Battery determines that emergency measures will be immediately undertaken to assure the stability of the building. The emergency intervention consists of supporting the Coidavid 3rd level by wooden carpentry starting from the ground level in order to consolidate the vaults and to stabilize the fissures in the walls.

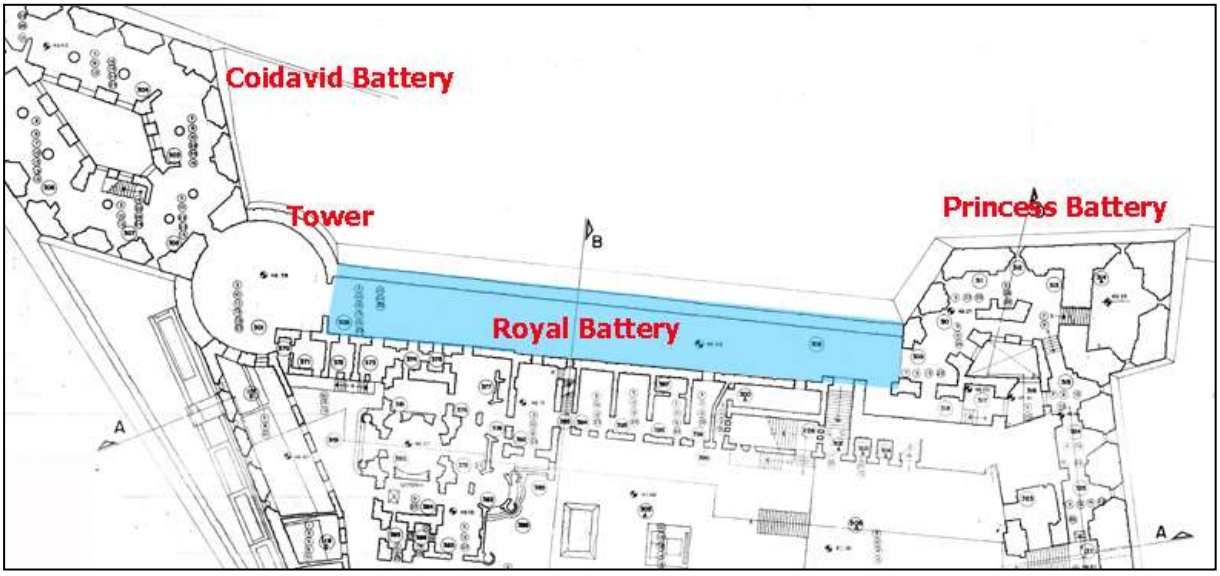


The above figure indicates the rooms where the collapse of the floors and of the vaults imposes the structural intervention; the room 3R was partially consolidated by using cement during the 1950 restoration, while the 2L room

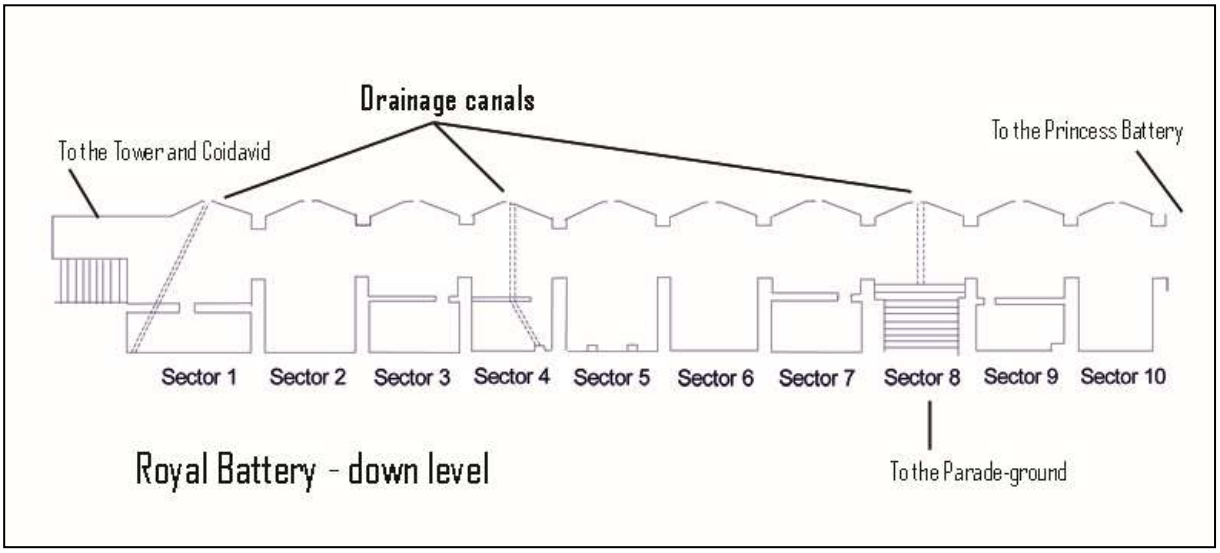
was stabilized by wooden carpentry during the restoration of 1982, and represents the example of functioning system for making simple and proper support to carry out the structural temporary consolidation of the building. The frames might allow ensuring the structural stability of the building in order to have the time necessary to define the details of the structural restoration. Once the structural restoration is made, the support frames should be removed room by room in order to make it possible for the definitive stabilization of the building, by rebuilding the floor and connecting horizontally the walls. During this time, the restoration project will be defined according to the several necessities of the monument's conservation.

Royal Battery

The Royal Battery consists of two superimposed levels connecting the Tower, and consequently the Coidavid Battery, with the Princess Battery and the rest of the fortress. The upper level consists of an open terrace that was unprotected until the restoration of the 1980s, when a roof reproducing the original shape was built.



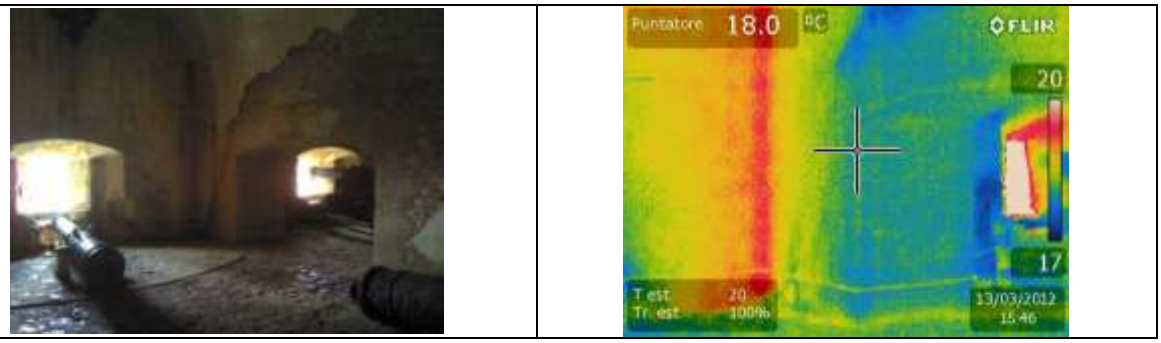
The survey of the battery confirmed that the down level is the most damaged because of the diffuse water infiltrations from the upper level of the Royal Battery, but also from the Parade-ground that opens on top of the staircase.

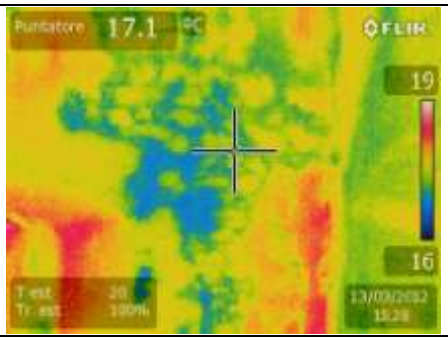


That the water filters from the Parade-ground was proved by the rainwater flowing in the left drainage canal (that close to the entrance staircase) coming from the upper levels through the new plastic pipe functioning as water collector in the 1980s restoration project, but actually malfunctioning and causing water filtration and saturation in the surrounding masonry.

Royal Battery - down level; all damages are due to the presence of water innside the walls

The survey of the external façade of the Citadel also allowed identifying the seepage water corresponding to the brick drip flap, where the rainwater flows and is collected by the canals that cross the pavement of the battery. Comparing the location of the seepage water to the IR thermography of the walls recorded inside the battery confirms that the water comes from the upper level causing the collapse of the structure; the degradation mechanism is in fact very complex and involves several parameters both chemical and physical. The most dangerous degradation mechanism is due to the chemical reactions that may changes the composition of the mortars because of the leaching of the lime from the matrix; as a consequence, the resistance of the wall decreases, so that every mechanical stress induced both by the wall dislocation and earthquake may cause the fissuring of the structures.

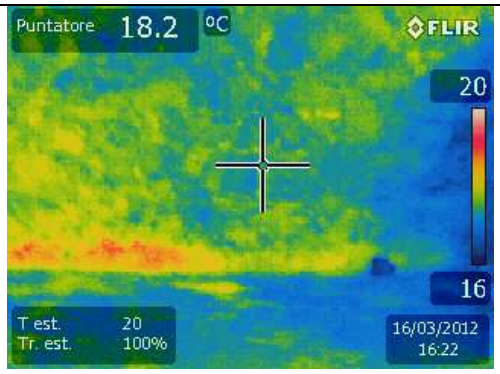




Royal Battery - down level; IR Thermography confirms that water come from the upper levels

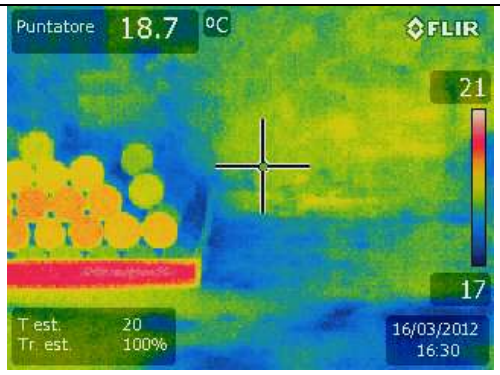
As the above images show, the degradation concentrates in the plaster both of the external and the internal walls causing that the finishing layer of mortar detaches and falls down, but also that biological patinas develop where water still saturates the masonry.

1



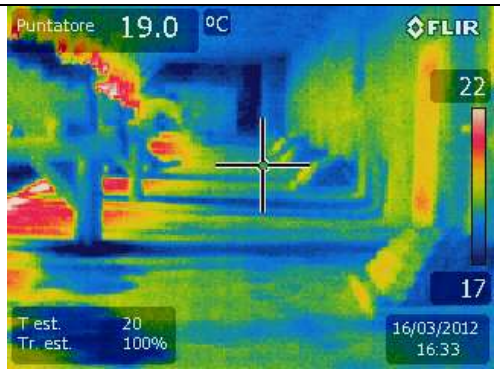
1A

2



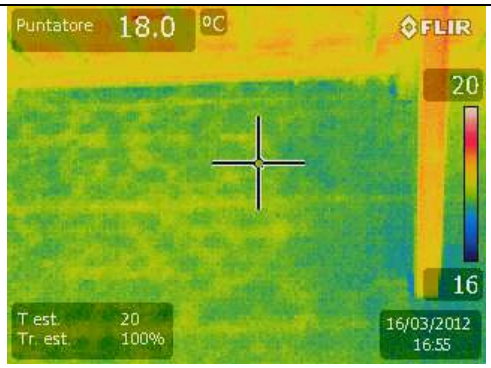
2A

3



3A


4



4A

Royal Battery, upper level: Comparison between natural color image and IR thermograph allows individuating the areas where water concentrates decreasing the temperature (blue and green areas).

The IR Thermographic investigation carried out in the down level of the Royal Battery confirm that the water comes from the upper terrace, where several quarry holes were opened by the responsible of the restoration works in the 1980s to inspect the consistency of the vaults. Although the original pavement was covered with a concrete slab in order to avoid rainwater penetrating the terrace roofing, the holes were kept open to provide support for the guns, being filled with pebbles only in order to permit every other inspection of the vault.

The sequence of images above proposed clearly demonstrates that the North wall of the battery is affected on top by the presence of water coming from the roofing (figure 4&4A), while at its bottom water growths by capillary coming from the terrace pavement (images 1&1A, 2&2A). Observing the images 3&3A confirms that water concentrates in the holes containing the gun supports, migrating by capillary till the base of the wall. The restoration of the terrace pavement is necessary to definitively solve this problem and preserve also the down level.

The upper level of the Battery is on the contrary well preserved because of the restoration works made by the ISPAN in the 1980s, with the rebuilding of the external wall and the roofing. The only areas where degradation is relevant correspond to the side in contact respectively with the Governor Place ruins in the East side, and that in contact with the Princess Battery at the opposite West side. The degradation is mainly caused by the water penetration from the top of the Governor Palace walls, which are unprotected, and from the terraces of the Princess Battery that are fissured. Making several infrared thermographies on the walls and the pavement of the battery allowed individuating the locations from where rainwater preferably enters. The presence of high concentration of water inside the pavement was not a surprise both because of the results of the investigations carried out in the lower level, and owing to the presence in the restored floor of several quarry holes filled by stone pebbles, corresponding to the location of the gun carriages, from where rainwater enters the filling of the below vault. Furthermore, since the vaults are filled with pebbles and clay, the water is retained for a long time and slowly released causing the Karstic processes that chemically affect the mortar integrity.

The other negative element is due to the presence inside the restored masonry of soft white efflorescence, which might be due to the addition to the mortar of small quantities of cement. This aspect will be better and properly discussed after the analytical investigations to be carry

out in Rome on the taken samples. In case of use of cement mortars for the restoration, the removal of this mortar is necessary to avoid that the soluble salts contained in the cement further affect the structure of the masonry.

Royal Battery - upper level; the North wall clearly shows the restoration boundary where salt growth

Restoration interventions

The restoration of both levels is strictly related because the degradation of the plasters and of the masonry of the lower level is due to the water percolating trough the pavement of the upper level. Indeed, rainwater accumulates in the layers beneath the existing pavement and penetrates the vaults of the down battery damaging the structures and increasing the risk of collapse of the vaults.

The lower level of the Royal Battery specifically needs to stop that water penetrates from the upper level affecting the conservation both of the masonry and of the plaster. As for the minimal restoration, most of the original plasters have to be consolidated by increasing their adhesion to the wall using suitable hydraulic mortars. Applying a thin layer of soft lime mortar, to reduce the risk of detachment from the brick surfaces, might consolidate the boundaries. The biologic patinas should be removed by applying suitable biocide by spray or by pack.

The restoration of the terrace might involve the dismantling of the existing pavement made of concrete, the excavation of the material filling the extrados to expose the original level of the pavement and its restoration with respect to the original shape and function, that is rehabilitate the original pavement level also restoring the locations of the guns. The waterproofing must then be obtained by treating the surface with suitable chemicals resistant to the mechanical stresses induced by the walking of the several people visiting the Citadel.

Princess Battery

The three levels of the Battery present different state of conservation owing to the different use and damages induced by the earthquake of the last century. The lowest level, which is the prosecution of the down level of the Royal Battery, is unfit for use because of the floor is partly collapsed.

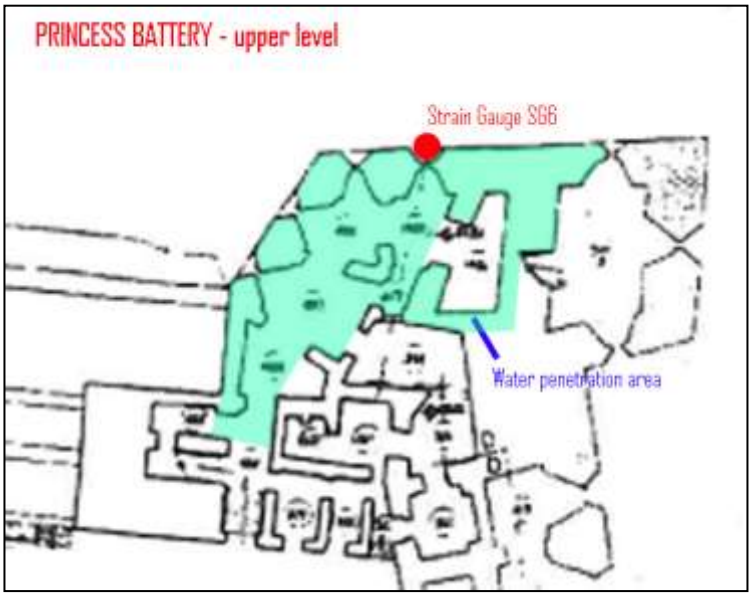
The intermediate level that is the natural connection with the upper level of the Royal Battery is actually closed because of the infiltration of water from the above level have caused structural damages in the rooms.

The last level, which was restored during the '80ths to host the exhibition regarding the restoration of the Citadel, is nowadays unfit for use because of the infiltration of water from the roofing and from the adjacent Queen Battery: the rainwater filters from the smoke leakage that are open in the ceiling, but also the fissures in the perimetrical walls allow that water enters the external walls of the battery.

This level of the Princesses Battery was then analyzed by IR thermography technique to assess the water distribution inside the masonry. The water penetrates both the East side and the West side of the battery coming from the thin fissures that are open into the roofing, which is heavily damaged instead it was restored about 20 years ago. Inspecting the roof indicates that the external perimeter row of concrete is partially detached from the wall allowing that rainwater may penetrate the walls diffusing inside the masonry. The review of the roof also confirmed that several small fissures affect the masonry layer of roofing, increasing the penetration of water inside the monument.

Princess Battery; the upper level is heavily infiltrate by rainwater that stagnates to the floor

Furthermore, the gun window East oriented is affected by a vertical fissure that starts from the smog window on the top of the wall; the Strain Gauge labeled as SG6 coupled with a data logger was then located transversally to the fissure in order to record both the enlargement of the fissure and the indoor temperature and relative humidity values.



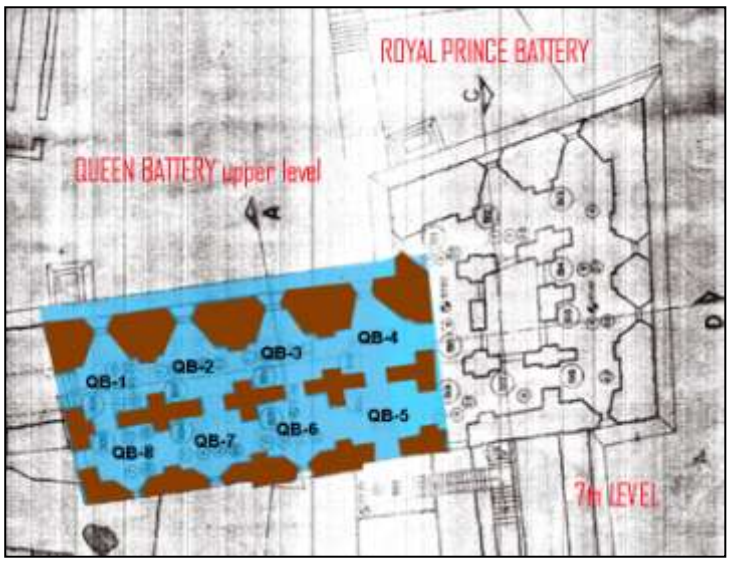
Restoration interventions

The review of the terrace covering the Princess Battery is needed in order to reduce the water penetration inside the rooms; also the vertical fissure affecting the East gun mouth has to be explored and filled by insulating waterproofing mortar in order to stop the rainwater penetration and the structural damage.

Two orders of problems seem affect the roof: the local displacement of the perimetrical concrete riddle and the elastic joints of the pavement. Both are in fact enlarged and allow that water penetrates inside the masonry. While the concrete riddle must be substituted with a similar and suitable riddle, the roof joints have to be sealed by special mortar that may ensure both the elasticity of the joint during the expansion and the insulation from the water

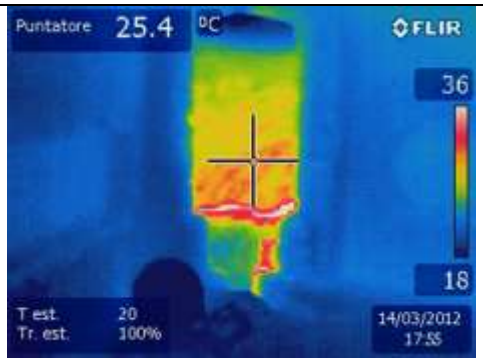
penetration. Silicon rubber mortars will be specifically tested in order to verify their suitability to solve both problems. Also liquid waterproofing insulating agents will be tested before applying to the roofing in order to verify the best treatment methodology to be sure that they work properly.

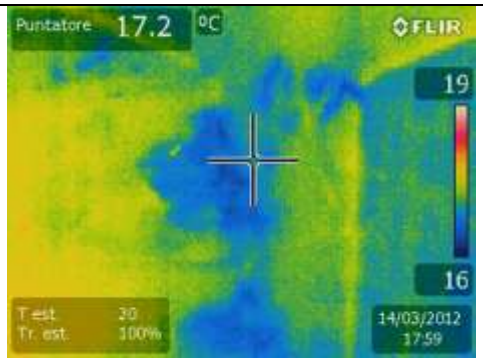
As for the terraces and roofing of the Princess Battery, the necessity to limit the border with transparent balustrades made of iron steel and poly-carbonate was agreed. The same solution will be adopted to close the windows and the gun windows in order to reduce the rainwater penetration inside the buildings.

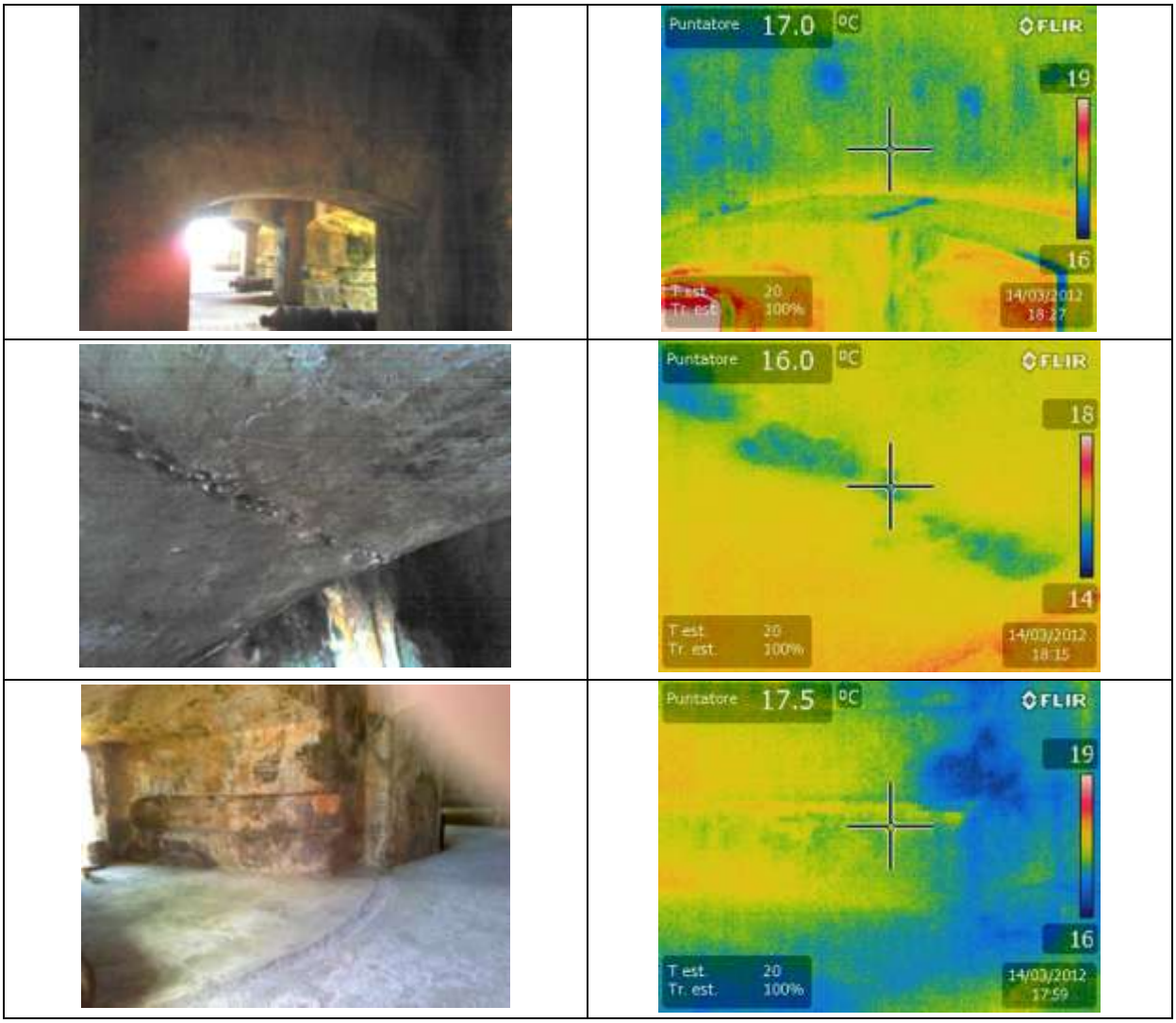


Queen Battery

The Queen Battery was analyzed from the structural point of view with peculiar regard to the presence of water in the masonry. The detailed description of each sector was recorded coupling the digital image with the IR thermography image.

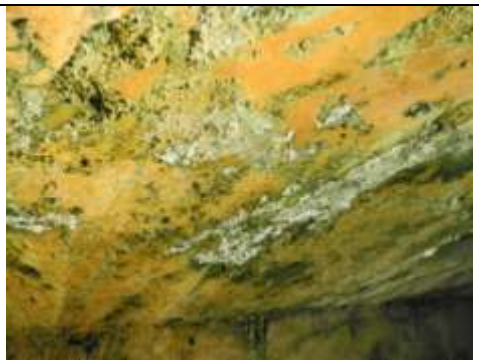






The state of conservation of the upper level of the battery is very bed due to the percolation of water inside the fissures in the vaults both on the south and on the north facades. On the contrary, the lower level is dry and well preserved (furthermore, it is used as dormitory) except for the west corner, where a large fissure of the extrados causes that rainwater enters the vault percolating till the pavement of the first level. Observing the fissuring distribution evidently appears that all fissures start from the centre of the vault in correspondence with the contact with the central wall that separate the two opposite galleries. This allows hypothesizing a sort of symmetry in the vault cracking due to the rotation of the north façade, which tends to tilt following the collapse of the vaults.

The collapse is also due to the chemical action of the seepage water that activates karstic processes inside the vault fissures. This causes that the lime and the binding mortar partly solubilizes releasing calcium hydrocarbon, which deposits in form of stalactites and carbonate concretions along the fissures and the surfaces of vaults. Furthermore, in the most exposed areas, where water evaporation is highest and the surface temperature increases because of the sun radiation, white crystalline efflorescence appear probably made of gypsum. Ascertain the nature of the efflorescence will allow identifying the cause of the degradation and the mechanism involved.

	
Queen Battery; calcium carbonate concretions	*Queen Battery; salt efflorescence*

Inspecting the roofing allows individuating some fissures affecting the pavement and a relevant volume of stone pebbles accumulated in the first sector of the roof (in correspondence of the sectors QB4 and QB5, where water enters in great quantity also wetting the lowest level.

Restoration interventions

Removing the stone pebbles from the roof of the Queen Battery results necessary to reduce the pressure on the structure, as well as to allow sealing the roofing to avoid that rainwater penetrates the vaults and the walls. Once this preliminary work is done, the cleaning of the surface and the fissures may start following the same methodologies applied to restore the Princess Battery roofing.

The other necessary action consists in the inserting plastic pipes of suitable diameter inside the existing gutters in order to properly collect and drain the rainwater avoiding that it penetrates inside the masonry causing the seepage water and the evolution of the karstic degradation processes. The pipes must have suitable size in order to deeply enter the drainage canals, also ensuring that no water is retained inside the masonry. The space around the pipe will be filled by hydraulic mortar, while bricks will camouflage the outgoing part.

Drawbridge Battery

The survey of the monument took into account the Drawbridge Battery, which is the actual main entrance to the Citadel. The entrance door shows the over imposing of several building phases made using different materials and probably techniques according to the chronology and the availability of the materials itself.

The following figure shows the sequence we were able to reconstruct both analyzing the masonries and discussing with Mr. Jean-Hérold Pérard, the engineer that directed the restoration works at the Citadel that gave us precious information about the supposed building sequence of the fortress.

Namely:

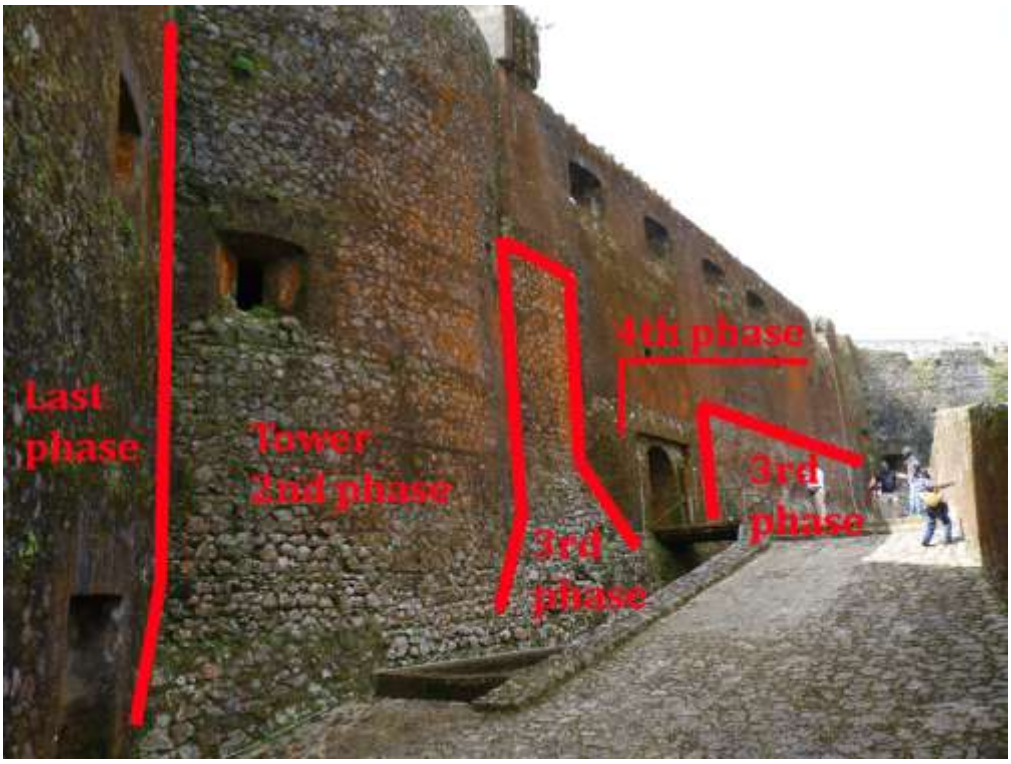
1st phase: is the inner defensive wall, which was quadrangular and, according to the description of Mr. Pérard, contains an edge whose foundation were included in the circular tower, while the perimeter wall is just in front of the drawbridge entering the fortress;

2nd phase: the tower that was probably built to increase the defense capability in the East front or to connect several elements of the fortress;

3rd phase: the perimeter wall that also defines the Royal Battery;

4th phase: the Princess Battery, the Prince Royal Battery and the Marie Louise Battery, and may be the brick entrance door;

5thphase: probably the Coidavid battery and the Grand Boucan Battery.



The sequence is absolutely provisional and needs to be verified on the base of the analytical data that will be collected on the taken samples.

The texture of the masonry little changes in the several phases because of the massive use both of stone fragments bound by mortar, and fired bricks also bound with mortar. However, taking samples allows verifying some peculiarities that might characterize the mortars.

Thanks to Mr. Pérard, part of the original 1st phase perimetrical wall was observed and sampled at the third level of the battery, where the wall is transversally cut by a second wall to which the external wall of the 3rd phase leans on.

From the conservative point of view, these structures are affected by water only, both because of the water capillary induced by the external storage tanks, and by the rainwater penetration from the upper levels, as IR thermography proved.

All surfaces are affected by the presence of biological patinas, whose color changes according to the exposure and to the nature of the biologics. Several samples were collected in order to characterize the pollutants and to define the best removing methodologies.

Restoration interventions

The provisional restoration of the Drawbridge Battery do not requires peculiar actions owing to the satisfactory state of conservation of the masonry. Nevertheless, since the most active degradation is due to the seepage water, the revisal of the drainage system (mainly that collecting the rainwater from the upper terrace) is necessary. Furthermore, to avoid that capillary affects the base of the walls, the emptying of all tank reservoirs along the perimetrical wall in front of the entrance and inside the court is recommended.

As for the restoration of the masonry, the same actions described for the urgent intervention of the down level of the Royal Battery might be adopted.

Ramiers: analysis and conservation of the site

The survey aimed to record the damages to several buildings present at the site and also to define the criteria for their conservation.

The Limekiln

The structure is relatively well preserved except some collapses due to the weather and probably to vandalism. The firing chamber is made of stones and bricks that are still retained by the binding mortar, which appears resistant to the decay induced by the environment.

The inner of the firing chamber shows that the surfaces are solid and compact, even if several varieties of trees have growth inside on the roof ruins.

The external arch of the firing chamber is made of bricks whose size differs from that of the structure. The last are thinner and similar to that found in Sans Souci owing the presence of some elements that are black inside and externally vitrified owing to the high firing temperature.

The 1st fort.

The entrance tower is fissured because of the earthquakes and the collapse of the roofing. The masonry is made of thin bricks and mortar, but to build the external canal and the main walls, rock fragments were also used. The plaster covering the masonry is hard and well adhering to the surfaces, as well as the hydraulic mortar of the pavement.

In the first room at the lower level a small well and a cooking kiln are present, probably to be used by the on guard soldiers.

	
Ramiers - the limekiln	*Ramiers - the 1st fort*

	
Ramiers - the 2nd fort	*Ramiers - The Queen Palace*
	
Ramiers - The Queen Palace	*Ramiers - the 3rd fort*
	
Ramiers - the 4th fort	*Ramiers - the barracks*

The 2nd fort.

The access to the fort was originally guaranteed by a large way made of stones and pebbles that still degrade the staircase in front of the drawbridge. The way and the staircase are well preserved, as well as the lower part of the entrance tower; on the contrary, both the mortar and the plaster are damaged and appear to be fragile and partially detached from the surfaces. This is probably due to the biological and mechanical solicitations due to the plants that abundantly growth inside the building. The water tank contains the ruins of the roofing and three small guns pertaining to the weapons of the fort. Small bricks about 15 mm thick are inserted in the masonry, but abundantly are dispersed in the ruins of the collapsed walls and roofing as well.

The Queen's Palace

This area is also identified as a farm and covers a large area that probably was accurately leveled to build the Palace. On the north side a wide storage tank was excavated to collect the rainwater; the cistern is well preserved and still plastered by hard mortar, while only few stalactites affect the ceiling due to the percolation of the rainwater trough the above soil.

A wall made of stones and mortar closes the court, which was finished by a plaster still preserving the red color of the wainscot and the yellowish color of the above wall. Though the wall is degraded, the color is resistant and well adhering to the plaster.

The inner building is preserved still the beginning of the second level, but the masonry is heavily damaged because of the plants and the weather. The restoration might involve both the structural problems and the preservation of the masonry to be treated as archaeological remains. However, the restoration project should be defined after the excavation of the whole area and the execution of the urgent intervention aiming to increase the stability of the vertical structures.

The main degradation we observe is due to the growth of several kinds of biological patinas, from where the red soft patina is prevailing.

The 3rd fort

The collapse of the roofing caused the fissuring of the entrance tower and of the walls; nevertheless, the fort is relatively well preserved as for the structure and the plasters. The degradation is mainly due to the plants that abundantly growth around, on and inside the masonry affecting the different structural elements. Also the biological patinas cover the surfaces ranging from the green moss to the most common and unidentified red soft patinas. In the reservoir tank three bronze guns are present resulting from the collapse of the wooden roofing; the gun carriages were not preserved because of the adverse conservation conditions. The presence of a sporadic vitrified brick is the element that reveals the direct report with the Sans Souci building materials.

The 4th fort

Is the better preserved owing to the good state of conservation both of the entrance tower and of the walls and moat. However, the plants invade all spaces causing the rupture of the masonry and the penetration of the rainwater. This accelerates the chemical degradation in both the mortar and the plaster.

The Barracks

The whole area is full of several kinds of trees and bushes that growth on the walls fissuring the masonry. Parts of the building are well preserved, and very good plasters cover the walls. Nevertheless, the degradation due to the environmental factors negatively impacts the structures, whose fragility increases from the top of the walls. The restoration may be planned after the excavation only.

Restoration interventions

The whole Ramiers area needs archaeological excavations and the evaluation of the real extent of the structures in order to project the restoration with a philological point of view,

respecting the original distribution of the military structures and the correct use of the spaces. For that, the surveys by helicopter or aerial photography is necessary.

Sampling

In order to characterize the nature of the original materials and the technology of both lime and bricks representative samples of mortars, plasters and bricks were taken from the monuments. The sampling took into account also the degradation products and patterns aiming to define the degradation mechanisms and to identify the best materials and methodologies for the restoration. A number of 157 samples were collected referring to the several materials and degradation products.

The labeling was defined as follows:

Site: HSS = Haiti Sans Souci; HCT = Haiti Citadel; HRM = Haiti Ramiers;
Year: the year of the sampling, that is 12 = 2012;
Location: capital letters indicate the peculiar site and orientation with reference to a plan;
Number: a maximum of three number represent the singular sample.

HAITI - FIELD ACTIVITY MARCH 2012

LIST OF THE SAMPLES

N°	Label	Location	Description
1	HSS/12/B1W/101	Chamber B1, wall west	Scales of degraded brick
2	HSS/12/B1W/102	Chamber B1, wall west	Mortar between the brick rows
3	HSS/12/B1W/103	Chamber B1, wall west	Mortar used to bind the stone blocks
4	HSS/12/B1W/104	Chamber B1, wall west	Finishing plaster
5	HSS/12/B1W/105	Chamber B1, wall west	Red color over the plaster
6	HSS/12/B1W/105A	Chamber B1, wall west	Plaster
7	HSS/12/B2N/106	Chamber B2, North wall	Mortar between the brick rows
8	HSS/12/B2N/107	Chamber B2, North wall	Brick with external deep green vitrified layer
9	HSS/12/B2N/108	Chamber B2, North wall	Red brick
10	HSS/12/B2N/109	Chamber B2, North wall	Brick with external green layer partially degraded
11	HSS/12/B2N/110	Chamber B2, North wall	Mortar between the stone fragments in the arch closed by stones and mortar
12	HSS/12/B2N/111	Chamber B2, North wall	Central pillar; brick of big size
13	HSS/12/B3S/112	Portico, B3 chamber; South wall	Yellow brick at the basement of the pillar
14	HSS/12/B3S/113	Portico, B3 chamber; South wall	Red brick under the sample 112
15	HSS/12/B3S/114	Portico, B3 chamber; South wall	Red degraded brick
16	HCT/12/CD1L/101	Coidavid, 1st set left side	Gun carriage in two pieces; traverse
17	HCT/12/CD1L/102	Coidavid, 1st set left side	Gun carriage in two pieces; soft root
18	HCT/12/CD3R/103	Coidavid, 3rd set right side	Gun carriage in two pieces; traverse
19	HCT/12/CD4R/104	Coidavid, 7th set right side	Gun carriage in two pieces; traverse
20	HCT/12/CD7R/105	Coidavid, 4th set right side	Gun carriage; left traverse

21	HCT/12/CD6L/501	Coidavid, 6th set left side	Scales of corrosion products on the cast iron cannon
22	HCT/12/CD5L/502	Coidavid, 5th set left side	Scales of corrosion products on the cast iron cannon
23	HCT/12/CD4L/503	Coidavid, 4th set left side	Scales of corrosion products on the cast iron cannon
24	HCT/12/CD3L/504	Coidavid, 3rd set left side	Scales of corrosion products on the cast iron cannon
25	HCT/12/CD2L/505	Coidavid, 2nd set left side	Scales of corrosion products on the cast iron cannon
26	HCT/12/CD1L/506	Coidavid, 1st set left side	Scales of corrosion products on the cast iron cannon
27	HCT/12/CD7R/507	Coidavid, 7th set right side	Scales of corrosion products on the cast iron cannon
28	HCT/12/CD5R/508	Coidavid, 5th set right side	Scales of corrosion products on the cast iron cannon
29	HCT/12/CD4R/509	Coidavid, 4th set right side	Scales of corrosion products on the cast iron cannon
30	HCT/12/CD3R/510	Coidavid, 3rd set right side	Scales of corrosion products on the cast iron cannon
31	HCT/12/CD2R/511	Coidavid, 2nd set right side	Scales of corrosion products on the cast iron cannon
32	HCT/12/CD1R/512	Coidavid, 1st set right side	Scales of corrosion products on the cast iron cannon
33	HCT/12/CD6L/601	Coidavid, 6th set left side, gun 501	Soft green patina of biologic pollutants
34	HCT/12/CD1L/602	Coidavid, 1st set left side, gun 506	Soft green patina of biologic pollutants
35	HCT/12/CD5R/603	Coidavid, 5th set right side, gun 508	Well adhering orange patina of biologic pollutants
36	HCT/12/BR9/DOW/711	Royal Battery, 9th set, gun 711	Wooden carriage, traverse
37	HCT/12/PGD/800	Citadel, Parade Ground	Fragments of the mortar used in the original building
	SANS SOUCI		
38	HSS/12/B0N/51	Entrance balcony B0, North wall: left pillar, base of the right column	Finishing plaster directly applied on the stone
39	HSS/12/B1S/52	Room B1, South wall: left pillar, right side	Fragment containing mortar and plaster; color is present as well
40	HSS/12/B1N/53	Room B1, South wall: lower layer of the wall	Scales of the finishing plaster with black and red color
41	HSS/12/B3N/54	Room B3, North wall: mortar detached	Scales and powder of the mortar
	CITADEL - COIDAVID		
42	HCT/12/CD2/LS/55	Coidavid, II° set left, South wall: inner wall, niche	Scales of the finishing plaster
43	HCT/12/CD2LS/56	Coidavid, II° set left, South wall: inner wall, niche	Binding mortar between the bricks
44	HCT/12/CD2LS/57	Coidavid, II° set left, South wall: inner wall, niche	Red brick scales
45	HCT/12/CD2LS/58	Coidavid, II° set left, South wall: inner wall at the left of the niche	Finishing plaster partly detached

46	HCT/12/CD3LW/59	Coidavid, III° set left, West wall at left of gun window	Mortar detached and degraded: scales and powder
	CITADEL - ROYAL BATTERY down level		
47	HCT/12/BR5N/60	Royal Battery, V° sector, West wall, Door: bricks filling the hole	Scales of the bricks
48	HCT/12/BR5N/61	Royal Battery, V° sector, West wall, Door: bricks filling the hole	Mortar between the bricks
49	HCT/12/BR5N/62	Royal Battery, V° sector, West wall, Door: Arch in contact with the pillar	Scales of the bricks
50	HCT/12/BR5N/63	Royal Battery, V° sector, West wall, Door: Arch in contact with the pillar	Mortar between the bricks
51	HCT/12/BR3N/64	Royal Battery, III° sector, North transversal wall	Scales of the bricks
52	HCT/12/BR3N/65	Royal Battery, III° sector, North transversal wall	Mortar between the bricks
53	HCT/12/BR3N/66	Royal Battery, III° sector, North transversal wall	Fragment of the stone of the masonry
	CITADEL - QUEEN BATTERY		
54	HCT/12/BRE1E/67	Queen Battery, 1st sector, East side: gun window left wall	Scales of brick and mortar
55	HCT/12/BRE1E/68	Queen Battery, 1st sector, East side: gun window left wall	Salt efflorescence
56	HCT/12/BRE3N/69	Queen Battery, 1st sector, East side: gun window left wall	Powder of mortar belove the efflorescence
57	HCT/12/BRE8W/70	Queen Battery, VIII° sector, West: wall between 8th & 7th sectors, arch	Scales of brick
58	HCT/12/BRE8W/71	Queen Battery, VIII° sector, West: wall between 8th & 7th sectors, arch	Mortar between the bricks
59	HCT/12/BRE8W/72	Queen Battery, VIII° sector, West: wall between 8th & 7th sectors, arch	Iron nail from the wall
60	HCT/12/BRE2E/73	Queen Battery, 2nd sector, East: right side of the vault above the gun window	Plaster with salt efflorescence
61	HCT/12/BRE4/74	Queen Battery, 4th sector: wooden gun carriage	Fragment of wood with yellow biological degradation
	CITADEL - ROYAL BATTERY - down level		
62	HCT/12/BRd10N/75	Royal Battery, down level, 10th sector, North wall built by stones and bricks	Binding mortar between the bricks and stones
63	HCT/12/BRd10N/76	Royal Battery, down level, 10th sector, North wall built by stones and bricks	Scales of brick

64	HCT/12/BRd10N/77	Royal Battery, down level, 10th sector, North wall built by stones and bricks	Mortar
65	HCT/12/BRd10N/78	Royal Battery, down level, 10th sector, North wall built by stones and bricks	Scales of stone
	CITADEL - ROYAL BATTERY - upper level		
66	HTC/12/BRUN/79	Royal Battery, upper level, external wall of the Governor Palace, North exposed: original masonry	Scales of brick
67	HTC/12/BRUN/80	Royal Battery, upper level, external wall of the Governor Palace, North exposed: original masonry	Mortar
68	HTC/12/BRUN/81	Royal Battery, upper level, external wall of the Governor Palace, North exposed: original masonry	Scales of limestone
69	HTC/12/BRUN/82	Royal Battery, upper level, external wall of the Governor Palace, North exposed: original masonry	Scales of limestone
70	HTC/12/BRUN/83	Royal Battery, upper level, external wall of the Governor Palace, North exposed: original masonry	Red organic patina
71	HTC/12/BRUN/84	Royal Battery, upper level, external wall of the Governor Palace, North exposed: original masonry	Scales of limestone probably travertine
72	HTC/12/BRUN/85	Royal Battery, upper level, external wall of the Governor Palace, North exposed: original masonry	Scales of brick
73	HTC/12/BRUN/86	Royal Battery, upper level, external wall of the Governor Palace, North exposed: original masonry	Mortar
74	HTC/12/BRUN/87	Royal Battery, upper level, Sector close to the Tower, North wall	Salt efflorescence
	LIME KILN lowest		
75	HFC/12/L/88	Lime kiln down, fire window, arch	Scales of brick
76	HFC/12/L/89	Lime kiln down, fire window, arch	Stone masonry, right side of the arch of the stokehole
77	HFC/12/L/90	Lime kiln down, fire window, wall left side of the fire window	Scales of brick
78	HFC/12/L/91	Lime kiln down, along the road: red outcrop	Red earth
	MILOT		
79	HFB/12/92	Brick kiln	Clay to make bricks, unfired
80	HFB/12/93	Brick kiln	Fragment of fired thin brick
81	HFB/12/94	Brick kiln	Clay inside the washing tank
	SANS SOUCI		
82	HSS/12/EW/950	Esplanade West	Outgropping reddish marl
	CITADEL - ROYAL BATTERY - upper level		
83	HCT/12/BRUN/95	Royal Battery, upper level, external wall of the Governor Palace, North exposed: restoration masonry	Mortar

	CITADEL - ROUND TOWER		
84	HCT/12/RTN/901	Round Tower, North side, ground level	Mortar
85	HCT/12/RTN/902	Round Tower, North side, ground level	Scales of stone
	CITADEL - DRAWBRIDGE BATTERY		
86	HCT/12/BLP/N/911	Drawbridge Battery, North wall, Right side of the drawbridge	Mortar
87	HCT/12/BLP/N/912	Drawbridge Battery, North wall, Right side of the drawbridge	Scales of stone
88	HCT/12/BLP/N/913	Drawbridge Battery, North brick wall of the entrance	Mortar between the bricks
89	HCT/12/BLP/N/914	Drawbridge Battery, North brick wall of the entrance	Scales of brick
90	HCT/12/BLP/N/915	Drawbridge Battery, North oriented inner stone wall, 1st level	Mortar
91	HCT/12/BLP/N/916	Drawbridge Battery, North oriented inner stone wall, 3rd level	Scales of stone
92	HCT/12/BPL/NV3/917	Drawbridge Battery, North oriented inner stone wall, 1st level	Mortar
93	HCT/12/BPL/NV3/917	Drawbridge Battery, North oriented inner stone wall, 1st level	Scales of stone
	RAMIERS		
94	HRM/12/FCU/91	Lime kiln upper, between Citadel and Ramiers; fire window, Arch	Mortar
95	HRM/12/FCU/92	Lime kiln upper, between Citadel and Ramiers; fire window, Arch	Scales of brick
96	HRM/12/FCU/93	Lime kiln upper, between Citadel and Ramiers; fire window, Arch	Scales of stone
97	HRM/12/FCU/94	Lime kiln upper, between Citadel and Ramiers; right stone charge wall	Scales of brick
98	HRM/12/FCU/95	Lime kiln upper, between Citadel and Ramiers; right stone charge wall	Mortar between the bricks
99	HRM/12/RD1/96	Fort N°1; Entrance tower: pavement	Plaster
100	HRM/12/RD1/97	Fort N°1; Entrance tower: pavement	Scales of brick
101	HRM/12/RD1/98	Fort N°1; Entrance tower: pavement	Mortar between the bricks
102	HRM/12/RD1/99	Fort N°1; Entrance tower: pavement	Mortar of the pavement
103	HRM/12/RD2/100	Fort N°2; Entrance tower, right pillar	Plaster
104	HRM/12/RD2/101	Fort N°2; Entrance tower, right pillar	Mortar between the bricks

105	HRM/12/RD2/102	Fort N°2; Entrance tower, right pillar	Scales of brick
106	HRM/12/RD2/103	Fort N°2; Entrance tower, right pillar	Fragments of erratic thin yellow and red bricks
107	HRM/12/RD2/104	Fort N°2; Entrance tower, right pillar	Red patina
108	HRM/12/PRC/105	Queen Palace, wale	Mortar from the entrance
109	HRM/12/PRC/106	Queen Palace, East wall; tall doors	Plaster covering the masonry
110	HRM/12/RD3/107	Fort N°3; drawbridge entrance tower	Mortar between the bricks
111	HRM/12/RD3/108	Fort N°3; drawbridge entrance tower	Scales of brick
112	HRM/12/RD3/109	Fort N°3; drawbridge entrance tower, right pillar	Finishing plaster
113	HRM/12/RD3/110	Fort N°3; drawbridge entrance tower	Scales of brick
114	HRM/12/RD3/111	Fort N°3; drawbridge entrance tower	Mortar between the bricks
115	HRM/12/RD3/112	Soldier Quarters; counterfort of the wale	Plaster
116	HRM/12/PR/113	Queen Palace; external wall	Red and yellow colored plaster
117	HRM/12/RD3/114	Fort N°3; erratic	Fragment of yellow thin brick
118	HRM/12/RD3/115	Soldier Quarters; masonry	Red biologic patina covering the green musses and colonized by white patina
119	HRM/12/RD3/116	Soldier Quarters; masonry	White patina colonizing the green musses
120	HRM/12/RD3/117	Soldier Quarters; masonry	Red organic patina
121	HRM/12/RD3/118	Soldier Quarters; erratic	Fragment of vitrified brick
	CITADEL - GOVERNOR PALACE		
122	HCT/12/GP/119	Governor Palace; biologic patinas	Red biologic patina with white lichen
	CITADEL - GUNS		**METAL SAMPLES**
123	HCT/12/BRD3/705	Royal Battery, down level; canons	Small scales from the gun
124	HCT/12/BRD3/706	Royal Battery, down level; canons	Small scales from the gun
125	HCT/12/BRD3/707	Royal Battery, down level; canons	Small scales from the gun
126	HCT/12/BRD3/708A	Royal Battery, down level; canons	Small scales from the gun
127	HCT/12/BRD3/708B	Royal Battery, down level; canons	Small scales from the gun
128	HCT/12/BRD3/710	Royal Battery, down level; canons	Small scales from the gun
129	HCT/12/BRD3/711	Royal Battery, down level; canons	Small scales from the gun
130	HCT/12/BRD3/712A	Royal Battery, down level; canons	Small scales from the gun
131	HCT/12/BRD3/712B	Royal Battery, down level; canons	Small scales from the gun
132	HCT/12/BRD3/712C	Royal Battery, down level; canons	Small scales from the gun

133	HCT/12/BRD3/712C	Royal Battery, down level; canons	Small scales from the gun
134	HCT/12/BRD3/716	Royal Battery, down level; canons	Small scales from the gun
135	HCT/12/BRU/767	Royal Battery, upper level; canons	Small scales from the gun
136	HCT/12/BRU/769	Royal Battery, upper level; canons	Small scales from the gun
137	HCT/12/OFQ/741	Officer Quarter; lead ingot	Fragment of lead ingot
138	HCT/12/OFQ/742	Officer Quarter; lead ingot	Fragment of lead ingot
	BIOLOGICAL SAMPLING		
139	HSS/12/B0S/001	B0, balcony base column	higher plants & ferns
140	HSS/12/B0S/002	B0, balcony base column	mosses & lichens
	HSS/12/B0S/003	B0, balcony base column	mosses & lichens
141	HSS/12/B0S/004	B0, column top	lichen
142	HSS/12/B0S/005	Chamber B1, wall North	plaster with black patina
143	HSS/12/B0S/006	Chamber B1, wall South	plaster with black patina
144	HSS/12/B0S/007	Chamber B2, wall South	plaster with black patina
145	HSS/12/B0S/008	Chamber B2, wall South	plaster with black patina
146	HCT/12/CD2L/009	Coidavid, 2st set left side; South wall	biological patina
147	HCT/12/CD2L/010	Coidavid, 2st set left side; North wall	biological patina
148	HCT/12/CD2L/011	Coidavid, 2st set left side; West wall	biological patina
149	HCT/12/CD2L/012	Coidavid, 2st set left side; North wall	biological patina
150	HCT/12/CD2L/013	Coidavid, 2st set left side; East wall	biological patina
151	HCT/12/CD2L/014	Coidavid, 2st set left side; West wall	biological patina
152	HCT/12/CD2L/015	Coidavid, 2st set left side; North wall	biological patina
153	HCT/12/CD3L/016	Coidavid, 3st set left side; West wall	biological patina
154	HCT/12/CD3L/017	Coidavid, 3st set left side; North wall	biological patina
155	HCT/12/CD3L/018	Coidavid, 3st set left side; North wall	biological patina
156	HCT/12/BR10N/019	Queen Battery; set 10, North wall	biological patina on mortar
157	HCT/12/BR10N/020	Queen Battery; set 10, North wall	biological patina on plaster

Security Plan

The security plan allows increasing both the safety of the visitors and the conservation of the monuments. The actions to be done differ for the three monuments according to their peculiarities. Nevertheless, two lines were identified: the first aims to increase the security of

the touristic visit, while the second is oriented to create the structural stability of the parts in risk of collapse, such as the Coidavid and the Queen Battery.

As for the first intervention line, the reduction of the circuit has been defined in order to avoid that public enters the dangerous parts of the Citadel complex, such as the ground level of Coidavid and both the Queen and the Royal Prince batteries.

Recommendation

1) Delimiting the touristic circuit by using provisional wooden barriers to avoid that the visitors may enter the dangerous areas such as the inner court and the ground level of the Coidavid Battery, and the Queens Battery.

2) The gun mouth and the windows should be protected as well by applying glasses or similar transparent resistant materials.

3) As for the roofing and the terraces, the visit circuit should be delimited by applying transparent and resistant barriers one meter far from the railing, to avoid that the visitors might directly overlook from the edge of the roofing.

Structural intervention

To reduce the risk of collapse of the buildings affected by fissuring and displacement of the walls, simple but effective measures have to be undertaken as matter of urgency.

Sans Souci Royal Palace

1) Temporary supporting of the walls

The temporary stability might be achieved by building inside the rooms metallic scaffolding that will mechanically support the walls. This solution is necessary to acquire all data and punctually recording the state of degradation of the masonry, useful to define the restoration project.

Once the scaffolding is effective, the structural monitoring should start by using strain gauges, accelerometers and data loggers to check the tilting induced in the vertical structures by the wind and the mechanical stresses.

The contemporary documentation of the degradation will be done. Furthermore, the presence of the scaffolding is also necessary to permit the execution of the restoration works, once defined the project.

2) Structural intervention

Increasing the stability of the structures means restore the building because of the impossibility to stabilize the vertical wall without insert external elements that may mechanically support the walls. Discussing with the local experts allowed hypothesizing the use of pillars made of carbon fibers and epoxy located in the corners of the rooms and connected by a horizontal beam made of the same materials at the original floor levels. The aerial circumambulatory made of light and resistant grids (the industrial roofing made by epoxy might be used) will contemporary increase the mechanical resistance of the supporting structure and make it possible the visit. The perimeter structure is 20-30 cm detached from the

original wall, but directly connected to this by inserting suitable carbon fiber elements into the holes where originally were located the beams supporting the pavement. The second level might be consolidated with the same technique, while the upper third floor will be consolidated by vertical triangularly shaped elements connected by resistant dralon lines treated with epoxy resin. The suggested solution derives from the experience made in the archaeological site of Herculaneum, where a supporting shell made of carbon fiber and epoxy resin was specifically projected, to resist to the earthquake shocks. However, the structure must be exactly calculated on the base of the mathematical modeling of the building, properly stressed in order to simulate the earthquake shocks.

Coidavid Battery

The building needs immediate intervention aiming to support the fissured vaults of the third level and the disconnected walls of the first and second level. The simplest and chipper solution seems to be the use of wooden frame to built the suitable castle using the same technique applied in the restoration of '80ths to provisionally support the roof of the second room of the left side of the battery. The intervention must be considered provisional and necessary to properly project the structural restoration reducing the risk of collapse. The restoration project will be developed by ISPAN on the base of the technical survey and the study of the fissuring pattern, but the precise knowledge of the original masonry composition will also allow identifying the best materials to use for the structural restoration.

Urgent Interventions to be undertaken

The restoration of the monuments of the History National Park should be developed in several phases. In the first step, urgent and necessary intervention might be done in order to ensure the stability of the building and the safety of the visitors. The second phase will be developed according to the priorities individuated by the responsible and the sequence functional to the conservation of the monuments. However, the philosophy is to proceed separately to the complete restoration of each building on the base of specific restoration project that take into account the peculiar necessities of each building.

The first phase of the intervention aims to stop the degradation by simple and chip activities that may be summarized as follows.

1) Increasing of the stability of plasters and mortars by the intrusion of suitable hydraulic liquid mortars and plastering of the boundaries with aerial mortar made of lime and sand. This activity will be done mainly in the down level of the Royal Battery and the staircase to the Parade court.
2) Cleaning of the surfaces affected by biological patinas both by spraying biocides in suitable concentration and applying cellulose packs saturated with the biocide. The intervention will include the down level of the Royal Battery, the staircase, the upper level of the Princess Battery, and part of the North wall of the upper level of the Royal Battery.
3) Chemical cleaning of the surfaces affected by salt deposition, efflorescence and incrustation by using ammonium hydro-carbonate solutions in suitable concentration

applied by pack. This activity will be made on part of the North wall of the Royal Battery only.

4) Mechanical removing of cement mortars eventually applied during the previous restoration works and causing degradation of the masonry. Also this activity will be made on the North wall of the Royal Battery, where cement mortars were used to consolidate the original wall and to built the restoration wall.
5) Locally strengthening by using suitable chemicals of the several materials (stone, mortar, plaster, brick, metal) that need the treatment, according to the necessities ascertained during the cleaning interventions.
6) Filling of the grouting and missing parts of the plasters and masonry with suitable mortar, according to the composition and the function of the masonry. This intervention will involve the plasters of both levels of the Royal Battery, the staircase and part of the upper level of the Princess Battery.

The same procedure might be applied to improve the conservation of the Royal Palace in Sans Souci, waiting that the structural restoration project is ready.

Cost of the urgent restoration interventions

The preliminary estimated cost for the urgent interventions in the Royal Battery at Citadel and Royal Palace at Sans Souci is 985.000,00 US$ as results from the following analysis.

The Royal Battery restoration yard will develop with the presence of one coordinator, one chief restorer, three restorers and six local levers for a period of eight weeks. The cost includes travel expenses and stay in Milot for two months. Movable scaffoldings, power generator, electric tools and equipments are included, as well as the restoration materials and tools necessary to arrange the restoration yard and lab.

The stabilization works of the Royal Palace in Sans Souci will take two months and the same time will take the photogrammetry.

As for the restoration works the estimated time is about two months using two different units composed like that working at the Citadel.

Evaluation of the State of Conservation of the Site inscribed in 1982 in the World Heritage List as "National Historic Park – Citadel, Sans Souci, Ramiers" Criteria (iv) (vi)	
Synthesis of the urgent restoration activities	
Preliminary cost estimation	
Item	**Cost US$**
CITADEL	

1) Increasing of the stability of plasters and mortars by the intrusion of suitable hydraulic liquid mortars and plastering of the boundaries with aerial mortar made of lime and sand. This activity will be done mainly in the down level of the Royal Battery and the staircase to the Parade court.	
2) Cleaning of the surfaces affected by biological patinas both by spraying biocides in suitable concentration and applying cellulose packs saturated with the biocide. The intervention will include the down level of the Royal Battery, the staircase, the upper level of the Princess Battery, and part of the North wall of the upper level of the Royal Battery.	
3) Chemical cleaning of the surfaces affected by salt deposition, efflorescence and incrustation by using ammonium hydro-carbonate solutions in suitable concentration applied by pack. This activity will be made on part of the North wall of the Royal Battery only.	
4) Mechanical removing of cement mortars eventually applied during the previous restoration works and causing degradation of the masonry. Also this activity will be made on the North wall of the Royal Battery, where cement mortars were used to consolidate the original wall and to built the restoration wall.	
5) Locally strengthening by using suitable chemicals of the several materials (stone, mortar, plaster, brick, metal) that need the treatment, according to the necessities ascertained during the cleaning interventions.	
6) Filling of the grouting and missing parts of the plasters and masonry with suitable mortar, according to the composition and the function of the masonry. This intervention will involve the plasters of both levels of the Royal Battery, the staircase and part of the upper level of the Princess Battery.	145.000,00
To increase the security of the monument several actions must be undertaken, such as:	
1) support the Coidavid third level by frames made of wood or metal to implement the structural stability and to facilitate the mapping of the building and the projecting of the restoration;	100.000,00
2) stop the water penetration from the Princess Battery and Queen Battery roofing by applying suitable fillers into the open fissures and a suitable liquid waterproofing compound to the whole exposed surface; walkways and protective barriers might be located to define the visit circuit, also avoiding that the visitors directly walk on the roofing. This activity might be carried out in very short time (about one month considering the cleaning and the treatment of the surfaces)	60.000,00
3) stop the water penetration inside the batteries by applying transparent glasses to the windows and to the gun windows;	
4) stop the infiltration of water in the vertical walls by inserting long pipes into the draining canals and building the external brick *gargouilles* to properly drain the rainwater;	
5) stop the water capillary into the external Drawbridge Battery walls by empting the water tanks in contact with them at the base;	

6) stop the rainwater penetration inside the Coidavid fifth level, the Officers Quarter and the upper level of the Royal Battery by ordinary maintenance of the roofing	50.000,00
Preliminary estimation	
Total cost of the urgent intervention at Citadel	**355.000,00**
SANS SOUCI	
1) Assuring the walls by building a suitable metallic scaffolding that contemporary allows both reducing the risk of collapse of the walls owing to a mechanical solicitation, and making it possible the direct inspection of the monuments in order to precisely define the project of the structural restoration	70.000,00
2) Photogrammetry mapping of the monument in order to record the metric reference values to be used to produce the mathematical modeling	150.000,00
3) Mathematical data processing of the photogrammetric mapping of the monument in order to obtain a model to which apply the different kind of supports useful to stabilize the building. The complex model resulting from the merge of the monument mapping and the supports will be analyzed with a dynamic system to simulate the earthquake stresses and to evaluate and calibrate the efficacy of the restoration structures.	75.000,00
4) Monitoring the monument by applying strain gauges, accelerometers and data loggers to record the tilting of the vertical walls	35.000,00
5) Restoration of the masonry according to the methodologies yet defined for the Citadel; namely:	
A) Increasing of the stability of plasters and mortars by the intrusion of suitable hydraulic liquid mortars and plastering of the boundaries with aerial mortar made of lime and sand. This activity will be done mainly in the down level of the Royal Battery and the staircase to the Parade court.	
B) Cleaning of the surfaces affected by biological patinas both by spraying biocides in suitable concentration and applying cellulose packs saturated with the biocide. The intervention will include the down level of the Royal Battery, the staircase, the upper level of the Princess Battery, and part of the North wall of the upper level of the Royal Battery.	
C) Chemical cleaning of the surfaces affected by salt deposition, efflorescence and incrustation by using ammonium hydro-carbonate solutions in suitable concentration applied by pack. This activity will be made on part of the North wall of the Royal Battery only.	
D) Mechanical removing of cement mortars eventually applied during the previous restoration works and causing degradation of the masonry. Also this activity will be made on the North wall of the Royal Battery, where cement mortars were used to consolidate the original wall and to built the restoration wall.	

E) Locally strengthening by using suitable chemicals of the several materials (stone, mortar, plaster, brick, metal) that need the treatment, according to the necessities ascertained during the cleaning interventions.	
F) Filling of the grouting and missing parts of the plasters and masonry with suitable mortar, according to the composition and the function of the masonry. This intervention will involve the plasters of both levels of the Royal Battery, the staircase and part of the upper level of the Princess Battery.	300.000,00
Preliminary estimation	
Total cost of the urgent intervention at Sans Souci	**630.000,00**
PRELIMINARY COST OF THE URGENT INTERVENTION US$	**985.000,00**

Remarks

The conservative restoration project has been sufficiently detailed during the mission thanks to the discussion with the other experts and the Haitian specialists; however more time is required to complete the conservation program, owing to the great number of variables involved and the extension of the sites.

We consider that the definitive conservation project will be ready in one month maximum so that it should be discussed in the month of May, before the new mission in June to collect the microclimate data and to verify the improvement of the structural restoration project.

Furthermore, the definition of methodologies to be applied to carry out the practical interventions may be changed according to the data of the IR thermography and that of the biological and chemical analyses.

As for the analyses, three months will be necessary to have the results owing to the great number of samples taken (about 160) and that of the XRF analyses of the metal artifacts (about 110); the about 420 IR Thermographies collected in the several parts of the monuments will be ready in one month and will be the useful base on which plan the intervention to stop the infiltration of water inside the masonry.

In the meantime, we hope that the Haitian partner will operate to ensure the structural stability of the damaged and unsafe parts according to the intervention guidelines we agreed during the mission.

The structural provisional interventions have to be applied in the Sans Souci Royal Palace and the Coidavid Battery in order to assure the stability of the building for the time necessary to define the structural restoration project.

Recommendations

The conservation of the monuments of the National History Park is actually strictly related to the urgent intervention to be carried out on each site and building.

According to the discussions held with several specialists that participate to the restoration works in the 1980s, some immediate interventions must be realized in order to decrease the risk of collapse of the structures both damaged and unsafe. The nature of the interventions changes according to the peculiarities of each site and the state of conservation of the buildings or the ruins.

The guidelines to be taken into account to realize the interventions are as follows.

Sans Souci

The Royal Palace needs to be structurally supported owing to the relevant height of the walls. The intervention must be realized in two separated steps, directly connected. However, the intercepting of the underground waters must be previously done to avoid that the walls damage because of the capillary.

In the first step the walls might be assured by building a suitable metallic scaffolding that contemporary allows both reducing the risk of collapse of the walls owing to the mechanical solicitation, and making it possible the direct inspection of the monuments in order to precisely define the project of the structural restoration. The presence of the scaffolding is also necessary to permit the execution of the restoration works, once defined the project.

The second step requires the mathematical data processing of the photogrammetric mapping of the monument in order to obtain a model to which applies the different kind of supports useful to stabilize the building. The complex model resulting from the merge of the monument mapping and the supports will be analyzed with a dynamic system to simulate the earthquake stresses and to evaluate and calibrate the efficacy of the restoration structures.

Realizing the modeling and the dynamic study might require about four months of work.

Citadel

As discussed in the summary report, the interventions to be realized to preserve the integrity of the Citadel differ for each building owing to the great differences they show in the degradation processes.

Two are the typical situations that impose to adopt different intervention lines: the structural decay and the safety of the visitors.

In the first case the most dangerous situation is represented by the Coidavid Battery, whose structural decay is clearly displayed by the dynamic monitoring performed during the mission: the fractures affecting the structural continuity of the point corner both of the building and of the spur move continuously confirming that the building is affected by a rotation. These damages seem to be due to the recent earthquake.

As for the safety of the visitors, the risk is homogeneously diffused to the entire monument because of the lack of protective barriers on the edges of the terraces and to the gun windows; furthermore, some parts of the batteries lacking of roofing are open and may be freely reached by the visitors, increasing the risk of falling.

Referring to the structural disease, most of the batteries of the Citadel suffer for the presence of seepage water that chemically degrades the mortars accelerating the structural degradation of the vaults and of the walls (particularly dangerous are both the Queen and the Prince Royal Batteries).

To increase the security of the monument several actions must be undertaken, such as:

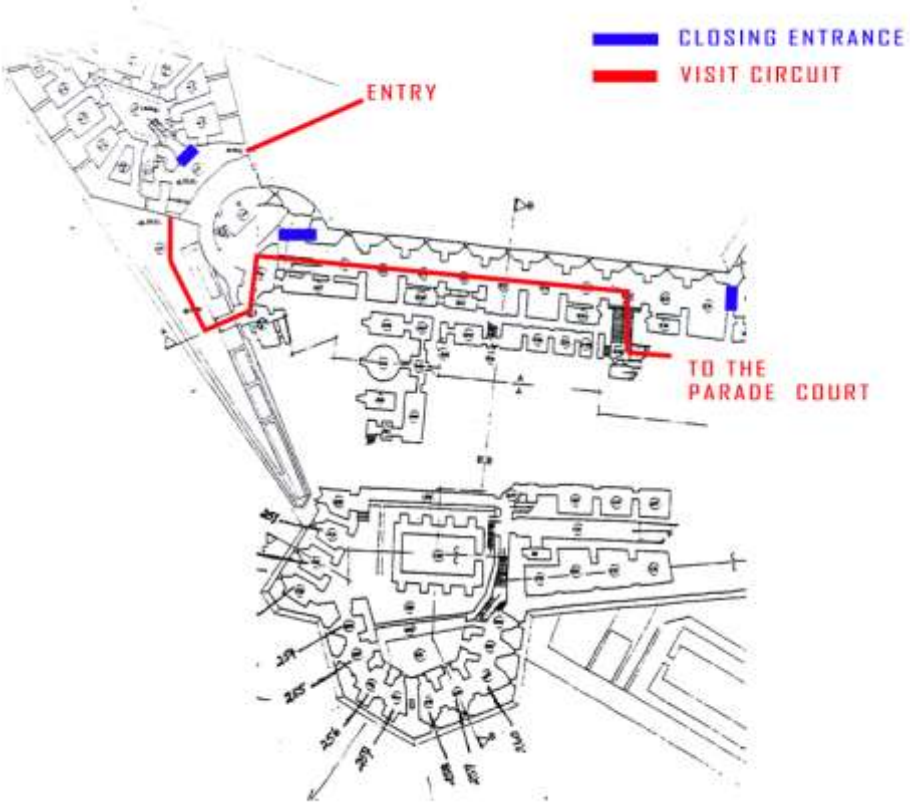
1) support the Coidavid third level by frames made of wood or metal to implement the structural stability and to facilitate the mapping of the building and the projecting of the restoration;
2) stop the water penetration from the Princess Battery and Queen Battery roofing by applying suitable fillers into the open fissures and a suitable liquid waterproofing compound to the whole exposed surface; walkways and protective barriers might be located to define the visit circuit, also avoiding that the visitors directly walk on the roofing. This activity might be carried out in very short time (about one month considering the cleaning and the treatment of the surfaces), while the estimated cost is about 60.000,00 US$ due to the special materials needed. Note that the job must be done by a restorer.
3) stop the water penetration inside the batteries by applying transparent glasses to the windows and to the gun windows;
4) stop the infiltration of water in the vertical walls by inserting long pipes into the draining canals and building the external brick *gargouilles* to properly drain the rainwater;
5) stop the water capillary into the external Drawbridge Battery walls by empting the water tanks in contact with them at the base;
6) stop the rainwater penetration inside the Coidavid fifth level, the Officers Quarter and the upper level of the Royal Battery by ordinary maintenance of the roofing.

Ramiers and lime-kiln

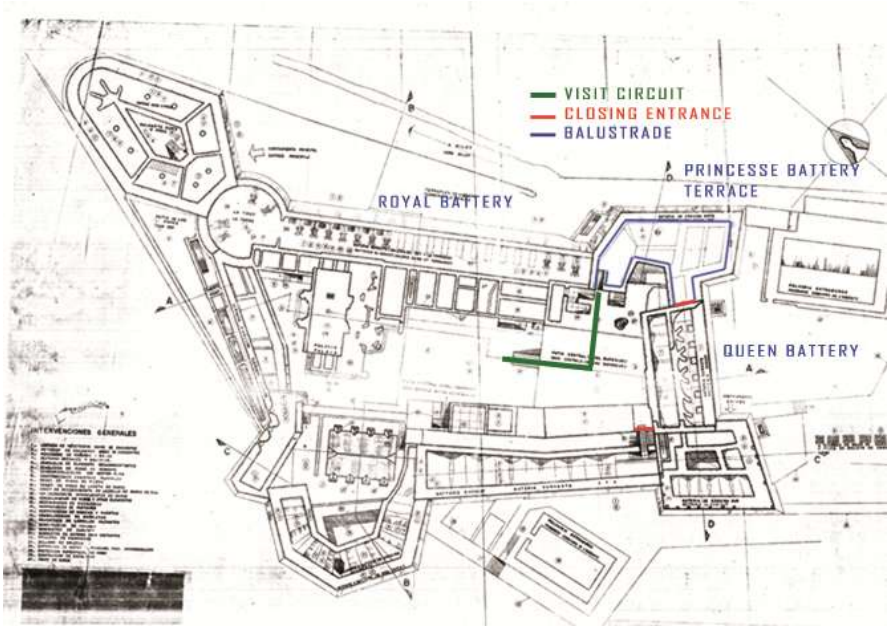
The only intervention to be done in order to reduce the degradation rate of the several buildings pertaining to the site consists in the capping of the walls by applying a hydraulic mortar made of lime, sand and brick powder. Cutting all plants that develop on the walls is also necessary to limit the mechanical and chemical damages to the masonry. Nevertheless, the archaeological excavation of the whole area is necessary to properly project the restoration of the forts and the ruins that compose the site.

ANNEX 1

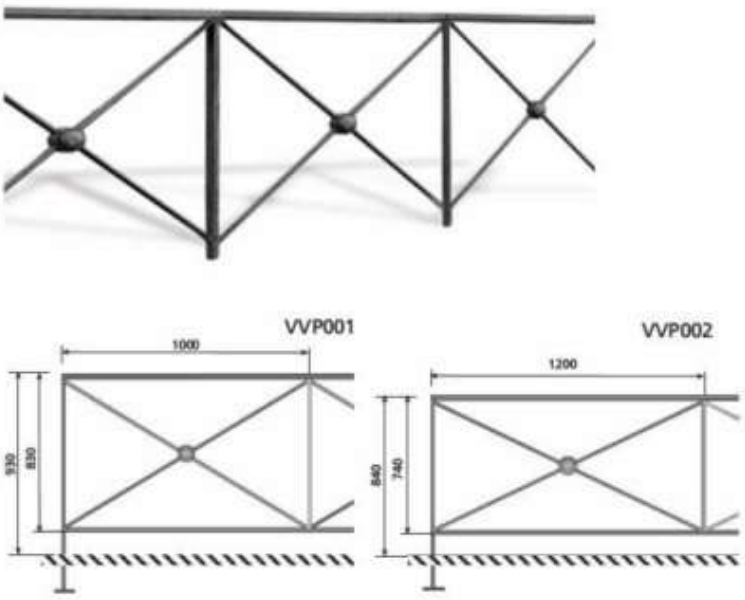
Urgent works to be undertaken prior to opening the visit circuit



The entrances to Coidavid and to the lower level of the Princess Battery must be closed by wooden frames, as well as the access to the Queen Battery from the Princess terrace and to the Prince Royal battery from the Parade court.



As for the Princess terrace, the balustrades must be partially transparent to guarantee the view of the historic important bays, but sufficiently resistant to reduce the risk of breaking by the visitors. The most used in the urban environments and in the archaeological sites are as follows.



This kind of balustrade is made of iron and may be connected with transparent foils of poly-carbonate or anti-shock glass.

ANNEX 2

Évaluation de l'état de conservation et des interventions d'urgence pour la sauvegarde des monuments du Parc National Historique de Haïti

La Citadelle et le Palais de Sans Souci

État de conservation

Les causes de la dégradation des zones de référence du Palais de Sans Souci et de la Citadelle même si elles se sont développées dans des circonstances différentes, dans un système ouvert pour le premier et semi-fermé pour la seconde, elles peuvent être considérées comme similaires par les mécanismes de mise en place des désordres des revêtements muraux, leur extension et leur gravité.
On peut donc distinguer deux causes principales de dégradation des superficies:

Palais de Sans Souci – Salle d'attente, mur Sud
Zone de rétention d'humidité et détachements

- La colonisation biologique diffuse sur une grande partie des superficies verticales ou horizontales, permet la stagnation humide et favorise les désagrégations, aussi bien macro que microscopique, des enduits et des éléments de maçonnerie comme les briques.

- La présence de couvertures biodétèriogènes, type algues vertes, lichens, mousses, bactéries, sur les zones humides en plus d'avoir un aspect inesthétique en associant l'édifice à une ruine, perturbe la circulation interstitielle des flux interstitiels.

- L'activité des éléments météorologiques associée à des phénomènes de remonté capillaire agit sur les enduits et les mortiers sous-jacents provoquant des désagrégations par lessivage et érosion, des phénomènes qui a leur tour, s'associent à l'action cryptocristalline des sels solubles présents dans les substrats.

La présence de contaminations biologiques associées à l'eau est responsable, de plus, de différences thermiques et mécaniques qui portent au détachement entre les couches des enduits plus superficiels et des crépis

Citadelle –Batterie Royale
Lacunes des enduits et infestations biologiques

Dans les paragraphes qui suivent sont décrits les états de conservation et les interventions de conservation d'urgence, dans les zones de référence dans lesquelles sont présents les plus grands flux de visiteurs et qui nécessitent, donc, une mise en sécurité des parcours.

La Citadelle

Batterie Royal 2° niveau

État de conservation

On peut relever une colonisation biologique généralisée surtout sur les murs Nord, autour des meurtrières et en relations aux passages de l'eau dans les fissures et les remontées capillaires.
Ces dernières sont responsables des détachements, souvent très étendus, des enduits et de la perte des sous-bassement où on peut trouver des badigeons rougeâtres.
Au niveau des arches, sont présentes des agrafes en fer fortement oxydé, probablement installées à postériori et destinées à supporter la structure en brique.

Opérations de restauration:

Les opérations de restauration porteront sur la mise en sécurité des enduits, le nettoyage des parements et leur consolidation et le traitement superficiel des fissures.

Restauration des enduits

Après une observation générale soignée de leur dégradation et une catalogation graphique de l'état de conservation, l'intervention principale sur les enduits consistera dans la réadhésion des couches de finition ou du crépi, détachés des supports muraux, aussi bien en pierre qu'en brique. Ces opérations seront exécutées en utilisant des mortiers pré-mélangés à base de chaux hydraulique, matrice fine et fluidifiants et pourront être mises en œuvre par injection et/ou percolation à l'intérieur des détachements.
Après le remplissage, l'utilisation de presses et soutiens pourra redonner aux enduits ainsi traités, sa forme originale, plane ou arrondie, dans le cas de voutes. L'application d'enduits dans les lacunes (solins) évitera la sortie des mortiers fluides de réadhésion et donnera aux panneaux d'enduit isolés un soutien ultérieur au support en mur. La composition de ces mortiers respectera celle des mortiers originaux en couleur, classification des matrices, et sera exécutée de façon à être le plus discret possible. Ces opérations devront être exécutées par du personnel hautement qualifié (restaurateur et aide-restaurateur).

C itadelle – Batterie Royale
Lacunes des enduits et infestations biologiques

Traitement biocide

La présence massive de colonisations biologiques rend le traitement nécessaire aussi bien d'un point de vue purement esthétique que sanitaire, en effets certaines présences biologiques peuvent être la cause de retenues humides et d'incompatibilités chimiques avec le substrat aussi bien enduit qu'en mur. D'après les analyses effectuées pendant cette mission, nous pourrons en déduire quels biocides auront les meilleurs résultats sur le traitement des couvertures biologiques. L'application sera exécutée par pulvérisation à basse pression ou par compresses, et l'élimination des résidus peuvent être exécutée par simple brossage avec des outils souples ou par projection de vapeur à basse pression qui le plus la faculté de regonfler certains organismes, types mousses et lichens, et favoriser leur détachement.

Nettoyage chimique et neutralisation des dépôts salins
Au cas où il sera nécessaire d'éliminer des patines incrustées ou des taches dues à la précipitation des sels solubles présents dans les eaux qui coulent en superficie, il sera opportun d'effectuer des compresses composées de fibre de cellulose et des complexantes de type bicarbonate d'ammonium et/ou E.D.T.A pour les incrustations tenaces.
Ces compresses ont en outre la possibilité de neutraliser les dépôts éventuels dus à la précipitation des sulfates aussi bien en superficie qu'à l'intérieur des ouches plus externes des revêtements.

Élimination des enduits incompatibles
Dans le cas où seraient présentes de vieillies restaurations utilisant des mortiers bâtard, ayant un pourcentage de ciment supérieur à 5%, ces derniers devront être déposés et remplacés par des mortiers compatibles avec les supports d'origine par leur composition chimique, la typologie des matrices et le type d'application (par ferrage éponge, etc.).

Reprise localisée des enduits, joints et briques
Les altérations généralisées ont apporté des phénomènes similaires sur des matériaux divers provocants souvent érosion et perte de matière.
Pour les mortiers de maçonnerie des murs en brique et pierre, il sera nécessaire un colmatage des lacunes par remplissage localisé de mortier toujours en harmonie avec les enduits d'origine.
Pour les reprises en brique, les interventions dépendront de l'ampleur de la lacune.
Là où on peut observer des fissure de petit grandeur un simple rejointoiement à base de chaux et poudre de brique sera suffisant; Là où au contraire les lacunes regroupent de larges zones et sont inesthétiques, on pourra agir par remplacement des briques entières.

Consolidation localisée des supports et revêtements muraux.
Dans le cas où sont présents, surtouts sur les voutes, des zones de dégradation avec des phénomènes de désagrégation et exfoliation, il sera nécessaire d'intervenir en consolidant les parements par application de consolident adéquats.
Dans ce cas, on pourra utiliser des solutions de silicate d'éthyle appliqué en concentration croissante (alcool), sans jamais arriver à la saturation du tissu capillaire des matériaux en question.
Pour des consolidations plus superficielles, comme des badigeons des sous-bassement, on pourra utiliser des solutions de résines acryliques (type PRIMAL E330S) toujours en solution alcoolique.

Rebouchage des fissures
Sur l'ensemble des fissures, présentes surtout en voute, il sera nécessaire d'effectuer un colmatage superficiel des ouvertures.
La consolidation profonde des fissures fait partie du traitement structurel et n'est pas incompatible avec le traitement des superficies.
Dans ce cas, on pourrait utiliser, comme colmatage, des mastics acryliques plastiques pour supporter les éventuels mouvements futurs des fissures, suivit par l'application de mortier hydraulique (comme vue précédemment) pour la finition des zones plus superficielles.

Escalier d'accès à la place d'arme
De la Batterie Royale au 2° niveau, on accède, par un escalier en brique, à la place d'arme.
Dans ce cas aussi, des interventions de restauration des superficies devront être mises en œuvre, pour la mise en sécurité du parcours ouvert au publique.

Restauration des enduits

L'intervention principale consistera dans la réadhésion des couches de finition ou de crépi, détachées des supports muraux, aussi bien en pierre qu'en brique.

Ces opérations seront exécutées en utilisant des mortiers pré-mélangés à base de chaux hydraulique, matrice fine et fluidifiants et pourront être mises en œuvre par injection et/ou percolation à l'intérieur des détachements.

Après le remplissage, l'utilisation de presses et soutiens pourra redonner aux enduits ainsi traités, sa forme originale, plane ou arrondie, dans le cas de voutes.

L'application d'enduits dans les lacunes (solins) évitera la sortie des mortiers fluides de réadhésion et donnera aux panneaux d'enduit isolés un soutien ultérieur au support en mur.

La composition de ces mortiers respectera celle des mortiers originaux en couleur, classification des matrices, et sera exécutée de façon à être le plus discret possible.

Ces opérations devront être exécutées par du personnel hautement qualifié (restaurateur et aide-restaurateur).

Traitement biocide

La présence massive de colonisations biologiques rend le traitement nécessaire aussi bien d'un point de vue purement esthétique que sanitaire, en effets certaines présences biologiques peuvent être la cause de retenues humides et d'incompatibilités chimiques avec le substrat aussi bien enduit qu'en mur.

D'après les analyses effectuées pendant cette mission, nous pourrons en déduire quels biocides auront les meilleurs résultats sur le traitement des couvertures biologiques.

L'application sera exécutée par pulvérisation à basse pression ou par compresses, et l'élimination des résidus peuvent être exécutée par simple brossage avec des outils souples ou par projection de vapeur à basse pression qui le plus la faculté de regonfler certains organismes, types mousses et lichens, et favoriser leur détachement.

C itadelle – Escalier d'accès à la place d'arme
Lacunes des enduits et infestations biologiques

Nettoyage chimique et neutralisation des dépôts salins

Au cas où il sera nécessaire d'éliminer des patines incrustées ou des taches dues à la précipitation des sels solubles présents dans les eaux qui coulent en superficie, il sera opportun d'effectuer des compresses composées de fibre de cellulose et des complexantes de type bicarbonate d'ammonium et/ou E.D.T.A pour les incrustations tenaces.

Ces compresses ont en outre la possibilité de neutraliser les dépôts éventuels dus à la précipitation des sulfates aussi bien en superficie qu'à l'intérieur des ouches plus externes des revêtements.

Rebouchage des fissures

Dans cette zone, sont présentes des lacunes d'enduit plus superficielles, dues au phénomène de dissolution de la matrice et au vandalisme.

Il conviendra donc d'effectuer des masticages avec des mortiers adéquats pour l'harmonisation visuelle aller jusqu'au colmatage des plus petites fissures.

Batterie des Princesses

Ici sont présentes les même dégradations des zones déjà décrites avec une présence plus importante d'enduits modernes et la nécessité d'une recherche stratigraphique des enduits d'origine.

Restauration des enduits

L'intervention principale consistera dans la réadhésion des couches de finition ou de crépi, détachées des supports muraux, aussi bien en pierre qu'en brique.

Ces opérations seront exécutées en utilisant des mortiers pré-mélangés à base de chaux hydraulique, matrice fine et fluidifiants et pourront être mises en œuvre par injection et/ou percolation à l'intérieur des détachements.

Après le remplissage, l'utilisation de presses et soutiens pourra redonner aux enduits ainsi traités, sa forme originale, plane ou arrondie, dans le cas de voutes.

L'application d'enduits dans les lacunes (solins) évitera la sortie des mortiers fluides de réadhésion et donnera aux panneaux d'enduit isolés un soutien ultérieur au support en mur.

La composition de ces mortiers respectera celle des mortiers originaux en couleur, classification des matrices, et sera exécutée de façon à être le plus discret possible.

Ces opérations devront être exécutées par du personnel hautement qualifié (restaurateur et aide-restaurateur).

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Stratigraphie des enduits

Afin de mettre en évidence la présence de phases successives d'enduits, il sera nécessaire d'effectuer des fenêtres stratigraphiques en recherche, sur les murs et les voutes.

Ces sondages seront exécutés en ouvrant des "fenêtres" (5cm x 5cm) par moyens essentiellement manuel de type scalpels, reportés sur des graphiques et détaillés par un dossier photographique.

Élimination des interventions modernes

Pendant les opérations préliminaires à la restauration, il pourra être décidé la dépose de toute intervention non originale, qui ne serai pas en harmonie aussi bien esthétique que chimique avec les couches d'origine.

Les techniques de dépose dépendront de la nature de ces interventions successives et de leur épaisseur.

On pourra donc utiliser des méthodes purement mécaniques pour la dépose des mortiers modernes, surtout ceux contenant du ciment et des méthodes chimiques pour la dépose des badigeons modernes.

Restauration des enduits

L'intervention principale consistera dans la réadhésion des couches de finition ou de crépi, détachées des supports muraux, aussi bien en pierre qu'en brique.

Ces opérations seront exécutées en utilisant des mortiers pré-mélangés à base de chaux hydraulique, matrice fine et fluidifiants et pourront être mises en œuvre par injection et/ou percolation à l'intérieur des détachements.

Après le remplissage, l'utilisation de presses et soutiens pourra redonner aux enduits ainsi traités, sa forme originale, plane ou arrondie, dans le cas de voutes.

L'application d'enduits dans les lacunes (solins) évitera la sortie des mortiers fluides de réadhésion et donnera aux panneaux d'enduit isolés un soutien ultérieur au support en mur.

La composition de ces mortiers respectera celle des mortiers originaux en couleur, classification des matrices, et sera exécutée de façon à être le plus discret possible.

Ces opérations devront être exécutées par du personnel hautement qualifié (restaurateur et aide-restaurateur).

Batterie Royale 3° niveau

Cette zone, et plus particulièrement le mur Nord, a subi d'importantes restaurations dans la campagne d'il y a X temps.

D'après les analyses exécutées pendant la mission, on contrôlera en particulier la compatibilité chimique des enduits au mortier contenant du ciment, présents sur le site en continuité des enduits d'origine.

Une couverture biologique rougeâtre est, en plus présente sur une grande partie du mur Nord.

Toujours d'après les analyses, sera possible de connaitre les biotypes présents et leur éventuelle nocivité en relation aux supports d'origine aussi bien en enduit, qu'en pierre ou en brique.

C itadelle – Batterie Royale
Enduits modernes en parties haute et infestations biologiques rougeâtre.

On peut également observer de nombreux dépôts superficiels salins en relation surement avec l'utilisation aussi bien en superficie que sur les zones internes du mur Nord, de mortier contenant du ciment.

Élimination des enduits incompatibles

Dans le cas où seraient présentes de vieillies restaurations utilisant des mortiers bâtard, ayant un pourcentage de ciment supérieur à 5%, ces derniers devront être déposés et remplacés par des mortiers compatibles avec les supports d'origine par leur composition chimique, la typologie des matrices et le type d'application (par ferrage éponge, etc.).

Reprise localisée des enduits, joints et briques

Les altérations généralisées ont apporté des phénomènes similaires sur des matériaux divers provocants souvent érosion et perte de matière.

Pour les mortiers de maçonnerie des murs en brique et pierre, il sera nécessaire un colmatage des lacunes par remplissage localisé de mortier toujours en harmonie avec les enduits d'origine.

Pour les reprises en brique, les interventions dépendront de l'ampleur de la lacune.

Là où on peut observer des fissure de petit grandeur un simple rejointoiement à base de

chaux et poudre de brique sera suffisant; Là où au contraire les lacunes regroupent de larges zones et sont inesthétiques, on pourra agir par remplacement des briques entières.

Nettoyage chimique et neutralisation des dépôts salins

Au cas où il sera nécessaire d'éliminer des patines incrustées ou des taches dues à la précipitation des sels solubles présents dans les eaux qui coulent en superficie, il sera opportun d'effectuer des compresses composées de fibre de cellulose et des complexantes de type bicarbonate d'ammonium et/ou E.D.T.A pour les incrustations tenaces.
Ces compresses ont en outre la possibilité de neutraliser les dépôts éventuels dus à la précipitation des sulfates aussi bien en superficie qu'à l'intérieur des ouches plus externes des revêtements.

Traitement biocide

La présence massive de colonisations biologiques rend le traitement nécessaire aussi bien d'un point de vue purement esthétique que sanitaire, en effets certaines présences biologiques peuvent être la cause de retenues humides et d'incompatibilités chimiques avec le substrat aussi bien enduit qu'en mur.
D'après les analyses effectuées pendant cette mission, nous pourrons en déduire quels biocides auront les meilleurs résultats sur le traitement des couvertures biologiques.
L'application sera exécutée par pulvérisation à basse pression ou par compresses, et l'élimination des résidus peuvent être exécutée par simple brossage avec des outils souples ou par projection de vapeur à basse pression qui le plus la faculté de regonfler certains organismes, types mousses et lichens, et favoriser leur détachement.

Le Palais de Sans Souci

État de conservation

Tous les phénomènes de dégradation, aussi bien au niveau structurel que superficiel, sont à mettre en relation avec l'état «ouvert » dans lequel le Palais de Sans Souci est situé actuellement.
L'absence de toute protection et l'exposition aux éléments météorologiques, portent les phénomènes déjà vu pour la Citadelle à des niveaux paroxystiques, avec une colonisation biologique, la dégradation des structures et des surfaces murales étendue à la totalité du Palais.
Cependant, les élévations encore existantes, nous donnent une image, au-delà de la simple émotion, de la majesté et de l'élégance du bâtiment.
En partant du concept qu'une intervention de consolidation structurelle est inévitable, nous pourrions peut-être envisager une intervention d'urgence sur les enduits restants et sur les maçonneries en danger de chute.


Palais de Sans Souci – Salle d'attente, mur Sud
Détachement récent de parties d'enduit.

Ces opérations pourront se dérouler pendant l'étude de l'intervention structurelle qui nécessitera la mise en place d'un échafaudage jusqu'aux niveaux supérieurs avec la mise en sécurité des enduits par colmatage des vides et réfection des solins, purge des éléments irrécupérables et protection des surfaces les plus exposées aux intempéries.

Cette intervention d'urgence permettra la poursuite des visites dans de meilleures conditions de sécurité, l'étude dans sa totalité des phénomènes de dégradation et la mise en place d'un protocole pour la restauration définitive aussi bien au niveau structurel que purement archéologiques.

Opérations de restauration:
Les opérations de restauration porteront sur la mise en sécurité des enduits, le nettoyage des parements et leur consolidation et le traitement superficiel des fissures.

Restauration des enduits
Nous avons pu observer, presque en temps real, que les processus de désagrégation des enduits sont toujours en activité, avec le détachement récent de parties importantes d'enduit superficiel, phénomènes qui malheureusement sont destinés à s'accentuer avec l'apparition de nouvelles voix d'infiltrations d'eau.
Après une observation générale soignée de leur dégradation et une catalogation graphique de l'état de conservation, l'intervention principale sur les enduits consistera dans la réadhésion des couches de finition ou du crépi, détachés des supports muraux, aussi bien en pierre qu'en brique.
Ces opérations seront exécutées en utilisant des mortiers pré-mélangés à base de chaux hydraulique, matrice fine et fluidifiants et pourront être mises en œuvre par injection et/ou percolation à l'intérieur des détachements.
Après le remplissage, l'utilisation de presses et soutiens pourra redonner aux enduits ainsi traités, sa forme originale, plane ou arrondie, dans le cas de voutes.
L'application d'enduits dans les lacunes (solins) évitera la sortie des mortiers fluides de réadhésion et donnera aux panneaux d'enduit isolés un soutien ultérieur au support en mur.
La composition de ces mortiers respectera celle des mortiers originaux en couleur, classification des matrices, et sera exécutée de façon à être le plus discret possible.
Ces opérations devront être exécutées par du personnel hautement qualifié (restaurateur et aide-restaurateur).

Traitement biocide
La présence massive de colonisations biologiques rend le traitement nécessaire aussi bien d'un point de vue purement esthétique que sanitaire, en effets certaines présences biologiques peuvent être la cause de retenues humides et d'incompatibilités chimiques avec le substrat aussi bien enduit qu'en mur.
D'après les analyses effectuées pendant cette mission, nous pourrons en déduire quels biocides auront les meilleurs résultats sur le traitement des couvertures biologiques.
L'application sera exécutée par pulvérisation à basse pression ou par compresses, et l'élimination des résidus peuvent être exécutée par simple brossage avec des outils souples ou par projection de vapeur à basse pression qui le plus la faculté de regonfler certains organismes, types mousses et lichens, et favoriser leur détachement.

Nettoyage chimique et neutralisation des dépôts salins
Au cas où il sera nécessaire d'éliminer des patines incrustées ou des taches dues à la précipitation des sels solubles présents dans les eaux qui coulent en superficie, il sera opportun d'effectuer des compresses composées de fibre de cellulose et des complexantes de type bicarbonate d'ammonium et/ou E.D.T.A pour les incrustations tenaces.
Ces compresses ont en outre la possibilité de neutraliser les dépôts éventuels dus à la précipitation des sulfates aussi bien en superficie qu'à l'intérieur des ouches plus externes des revêtements.

Élimination des enduits incompatibles

Dans le cas où seraient présentes de vieillies restaurations utilisant des mortiers bâtard, ayant un pourcentage de ciment supérieur à 5%, ces derniers devront être déposés et remplacés par des mortiers compatibles avec les supports d'origine par leur composition chimique, la typologie des matrices et le type d'application (par ferrage, éponge, etc.).

Reprise localisée des enduits, joints et briques

Les altérations généralisées ont apporté des phénomènes similaires sur des matériaux divers provocants souvent érosion et perte de matière.

Pour les mortiers de maçonnerie des murs en brique et pierre, il sera nécessaire un colmatage des lacunes par remplissage localisé de mortier toujours en harmonie avec les enduits d'origine.

Pour les reprises en brique, les interventions dépendront de l'ampleur de la lacune.

Là où on peut observer des fissure de petit grandeur un simple rejointoiement à base de chaux et poudre de brique sera suffisant; là où au contraire les lacunes regroupent de larges zones et sont inesthétiques, on pourra agir par remplacement des briques entières.

Consolidation localisée des supports et revêtements muraux.

Sur les parties plus exposées comme les appuis des fenêtres, des zones de dégradation avec des phénomènes de désagrégation et exfoliation, il sera nécessaire d'intervenir en consolidant les parements par application de consolidant adéquats et de prévoir des couvertures, avec des matériaux (à définir ultérieurement) pour arrêter les infiltrations d'eau.

Palais de Sans Souci – Salle d'attente, mur Sud
Appui de fenêtre, zone de rétention d'humidité.

Dans ce cas, on pourra utiliser des solutions de silicate d'éthyle appliqué en concentration croissante (alcool), sans jamais arriver à la saturation du tissu capillaire des matériaux en question, suivi par la pose de protection résistent aux intempéries type couvertures en mortiers à chaux hydraulique.

Pour des consolidations plus superficielles, comme des badigeons des sous-bassement, on pourra utiliser des solutions de résines acryliques (type PRIMAL E330S) toujours en solution alcoolique.

Il est ne moins d'obligations la mise en sécurité des zones maçonnées isolée en élévations, avec des accrochages provisoires avant l'établissement d'un cahier de charge, et son application, qui rendra définitive la stabilité des partie en danger de chutes.

Rebouchage des fissures

Sur l'ensemble des fissures, présentes surtout en voute, il sera nécessaire d'effectuer un colmatage superficiel des ouvertures.

La consolidation profonde des fissures fait partie du traitement structurel et n'est pas incompatible avec le traitement des superficies.

Dans ce cas, on pourrait utiliser, comme colmatage, des mastics acryliques plastiques pour supporter les éventuels mouvements futurs des fissures, suivit par l'application de mortier hydraulique (comme vue précédemment) pour la finition des zones plus superficielles.