NATIONAL HISTORY PARK CITADEL-RAMIERS-SANS SOUCI – HAITI

Mission 14-29 May 2013
Contract N° 4500202908

Summary Technical Report

Rome, on June 24th, 2013

Introduction

The mission started on May 14th and aimed to:
1) Assess the safety measures carried out by ISPAN to guarantee the temporary conservation of the Coidavid Battery,
2) Assess the activities to improve safety in the touristic tour, mainly in the strongly damaged batteries, such as the down gallery of the Royal Battery and the lowest level of the Princess Battery,
3) Assess the state of conservation of the Queen and Royal Prince batteries,
4) Realize the topographic survey of the external surfaces of the monument in order to obtain the general plan and the fronts of each battery.
Mr. Costantino Meucci, expert in conservation of monuments, team leader, and Mr. Massimo Sabatini, expert in topographic survey, composed the mission team.

According to point 3 of the contract, regarding the assessment of the safety measures for Coidavid Battery and tourist circuit, at the moment of the survey was ascertained that:
1) Part of Coidavid vaults of the third level were supported by using wooden scaffoldings properly projected by Engineer J-H Pérard, which was especially charged by ISPAN for that;
2) The safety works were temporary stopped, but restart on May 25th, during our mission;
3) Only part of the recommendation present in the 2012 summary report were applied to improve the safety of the tourist, such as closing the access to the Coidavid Battery and to the gallery of the Royal Battery, and to lowest and highest levels of the Princesses Battery as well. On the contrary, no protection barriers were placed to protect the terraces and the roof areas commonly open to the public. However, the entrance to the monument is actually from the ground level of the Royal Prince Battery, on the south side of the monument.

Anyway, on May 26th the job to improve safety for the tourists started under the direction of Arch. Daniel Eli, charged by ISAPN for that. Nevertheless, we haven't the opportunity to visualize the details of the project.

1) Safety measures for Coidavid Battery

Building wooden scaffoldings that isolate the single levels, reaching the ceiling (figure 1), helped in supporting the vaults. The structures are strongly built in order to guarantee the highest resistance to the mechanical solicitations induced by the detached vaults (figure 2). However, due to bureaucratic causes, the work was temporary stopped, but restarted on 25th May, using all wooden frames that were recovered in the court of the battery (figure 3). The prolonged stop of the job risks to cause serious problems to the monument stability, because the weight of the vaults is distributed in inhomogeneous way, so that the unsupported areas may move independently. Indeed, the new wooden floors strongly connect the walls of the adjacent rooms (figure 4) increasing the general stability of the building, whilst the unsupported parts may suffer the mechanical solicitations induced by the wind, and the weight of the battery itself, mainly where large fissures affect the walls (figure 5) in the highly solicited areas.

Aiming to assess the efficacy of the safety measures carried out, as well as their effects on the building stability, the new fissure's monitoring has been performed using the same locations and tools of the monitoring taken in 2012 (figure 6).

The monitoring started on May 16th at 2:30 PM local time and was stopped on May 23rd at 10:00 AM. The probes were planned to record the data each 30 minutes, contemporary acquiring Temperature, Relative Humidity and Deformation. All strain gages recorded deformation in the range -8 ÷ +8 mm, except for SG3 probe that recorded in the range -5 ÷ +5 mm.

In order to verify the trend of the deformations and the efficacy of the monitoring system, all data loggers were readout every day between 9:00 and 10:00 AM.

Figure 7 shows the typical graph of the trend of the three measured parameters in the whole monitoring period, and refers to the location SG4, which resulted the most active in the variability of the deformation. However, comparing all detected values, and evaluating the absolute deformation of each location allows individuating that all fissures move, according to the peculiar orientation of the fissure with respect to the geometry of the building. Figure 8 clearly shows that in case of compression, location SG4 suffers the highest negative deformation, while the other locations only slightly move. On the contrary, the strongest enlargement has been recorded in location SG2 (figure 9) that is opposite to SG4.

Comparing all data and calculating the absolute deformation for each location confirms that each solicitation in SG4 location induces deformation of the others fissures (figure 10); in particular, after the maximum compression value of SG4 is reached, the structure tends to react enlarging all fissures, so that the maximum enlargement is recorded in the SG2 location, which starts to move strongly. On the

contrary, SG3 location that was expected to be the most stressed fissure owing to its peculiar location at the edge of the Coidavid, was stable and suffered really little symmetric deformation. This may be due to the stabilization works that supported the right side of the pavilion, contrasting the movement of the horizontal fissure SG3. However, the stress induced by the continuous deformation of the building negatively impacts on the structures that denounce misalignment of part of the wall (figure 11) in the most stressed area corresponding to the edge of the pavilion.
On May 25th we had a meeting with the project maker Mr. J-H Pérard aimed to discuss with him about the adopted solutions to stabilize the building. Analyzing all recorded data, and surveying the job allowed confirming the suitability of the project and of the technical solutions applied. Nevertheless, both agreed about the necessity to speed this practical activity to reach the safety of the monument as soon as possible (the end of job is prevue in about one month), but also suggest that the structural restoration will be project and carried out in very short time to avoid the risk of collapse of the entire structure.

2) Monitoring microclimate within the Coidavid Battery

Aiming to collect much information as possible on the microclimate behavior of the Battery, in the third set on the left side (the same monitored in 2012) seven data logger were placed respecting the same distribution of the previous monitoring in order to assess the best exhibition solution.
During the present monitoring, both doors connecting the set with the adjacent boxes were open to guarantee that air passes freely in the battery. Nevertheless, since the windows were closed by partly obscured glasses (useful to reduce the IR radiation entering the windows) the actual monitoring is able to reproduce the possible exhibition solution. The data has been recorded daily from all locations in order both to assess the evidence of anomalous trend and to compare the values of each peculiar location with those of the reference average probe. Indeed, two temperature probes were placed outdoor on the north façade and in the inner court respectively, while the remnant four probes collect data of the wall temperature on ancient lime mortar and restoration cement mortar respectively.
Table 1 summarizes the maximum, minimum and average values recorded in the short monitoring time from 16 to 23 May 2013, while figure 12 shows how the values vary with respect to the average temperature value of each location. Figures 13a÷g show the charts recorded during the microclimate monitoring.
The external reference probes in the locations H1T1 and H2T2 have great differences between the maximum and minimum values, but the difference decreases in the inner court of the battery, which is sun exposed and protected by the wind. The environment values refer to the temperature recorded by the probes located close to the wall surface and allow evaluating that all probes little differ according to the peculiar location. This confirms that the geometry of the chamber and the protections applied to the windows and to the arches contribute to stabilize the indoor

microclimate. However, opening the doors reduces the relative humidity values in the chamber, but not eliminates the phenomenon of the water condensation on the wall, as the Dew Point trends and values confirm. Indeed, the locations from H3 to H6 shows that the water condensation temperature is often greater than the mortar or concrete temperature, while in the same location the RH % values often reaches the saturation point. Thus, liquid water forms on the walls, but also comes from the top of the arches as the thermal images show. Furthermore, looking at the images recorded outside and inside the closed cannon embrasure (set 3L) confirms that completely closing the room increases the frequency of the water condensation on the walls and consequently the risk of damage of the plasters (figure 14)

3. Topographical survey of the monument

As for the project and the contract, one of the activity to be carry out aimed to obtain the digital and graphic representation of the external surfaces of the whole monument, in order to assess the reliability and usefulness of the drawings given by ISPAN as base of the next projecting activity. The survey has been performed by a total station and allowed obtaining a 3D representation of the monument in its complexity (figures 15, 16, 17, 18, 19). The comparison with the take-over obtained in the years 1980-82 has shown that these drawings do not match perfectly with the present 3D sky-line representation, probably due to the increased precision of the new instruments. Consequently, in order to prepare the best suitable graphic material to support the restoration project of the Coidavid Battery, the plan of the third level of the pavilion was taken (figure 20), also locating the collapses of the vaults and the height of the pavement in several locations.

Furthermore, the 3D sky-line recording of the inner court connecting the Princess, Queen and Prince Royal Batteries was taken in order to obtain the front representation of each battery suitable to record the distribution of the degradation patterns and to plan the restoration activities. In particular, the front of the Queen Battery has been connected with the plan recorded at the last floor level (figure 21), where the strain-gage monitoring system was placed to monitor the deformation of the fissures affecting the vault of the second chamber in the west side of the battery.

4. Preparing the restoration project

Many activities were also carried out in order to properly support the projecting of the restoration to be carried out in the next July mission.

4.1. Monitoring microclimate within the Princess Battery

On May 23rd the microclimate system was placed in the upper level of the Princess Battery in order to collect data regarding the measures to be applied to properly use the level for the exhibition. The probes were distributed within the level according to the plan proposed in figure 22: location A is the reference probe recording both average temperature and relative humidity, while location G contains the external reference temperature in the north exposed front. The remnant locations will record

wall temperature by contact probe and wall average temperature and relative humidity each 30 minutes. The first monitoring assessment carried out on May 25th has confirmed that all probes work correctly and also allowed projecting the closing of all open windows on June 15th in order to obtain significant data referring to the optimal exhibition placing of the level after the rehabilitation work of the terrace.
Contemporary, the recording of FLIR images has been made aiming to individuate the anomalies in the water distribution inside the masonry. The comparison among the pictures recorded in the several rooms of the battery allows verifying that water affects the masonry both because of the infiltration from the roofing, and the capillary at the bottom of the walls, owing to the stagnation of liquid water at the floor level, when rainwater filters inside the battery (figure 23).

4.2. Monitoring the mechanical solicitations of the Queen Battery

On May 24th the dynamic deformation monitoring system made of five probes was placed within the second chamber of the upper level of the Queen battery (figure 24) in order to monitor continuously the movements of the fissures affecting both the walls and the vault. The data collected on May 25th show that all fissures suffer minimal deformations that are generally opposed: SG4, SG6 and SG3 recorded negative absolute deformation (the fissures tend to close by compression), while SG2 and SG5 tend to enlarge. However, the general trend of deformations will be properly evaluated after a long monitoring time.

4.3. Analyzing the state of conservation of the Prince Royal Battery

The levels of the battery were investigated both visually and by IR camera in order to record the distribution of the typical damages and the presence of water inside the masonry. During the visual survey sketches and photos were taken, aiming to simplify the graphic representation of the damages (figure 25) to be properly recorded in general degradation tables, according to the labeling of the rooms proposed in figure 26.
Contemporary, the instrumental investigation of the most damaged areas has been carried out in order to collect images representing the distribution of water inside the masonry. Using the IR camera, which gives both color and IR pictures of the investigated area, made this peculiar survey. Figure 27 shows an example of the collected information. A total number of about 140 pictures were recorded analyzing the battery chambers.
Observing figure 27 allows individuating in the high relative humidity value the main cause of biological degradation: indeed, all walls are covered by green algae patina that develop thanks to the water absorbed by air and salts extracted from the masonry. However, the IR images show that water mainly concentrates in the upper vault levels and at the bottom of the wall, as well as in the less sun exposed surface (the right side of the arch). Thus, the presence of water is due both to infiltration from the ceiling, and to the accumulation at the pavement, which was plastered by cement mortar during the last restoration works. However, the texture of the masonry also affects the

distribution of water inside the masonry when rainwater penetrates inside the vaults (figure 28) casually distributing into the walls.

4.4. Analyzing the external front of the batteries by IR camera

The investigation of the external surfaces of the batteries (namely Princess, Queen and Royal Prince Batteries) has been possible because of the favorable weather conditions that ensure the penetration of rainwater in the night and its evaporation during the day. Figure 29 shows an example of integrated representation of the water distribution into the masonry of the Queen Battery obtained merging the skyline front from topographic survey and the IR pictures recorded in the same day and hours. Observing the figure clearly appears that water enters the wall from top, owing to both the fissures in the vault of the upper level, and to the drainage system that do not works properly. The blue areas, indeed, represent the coldest areas where water preferably accumulates; this is true for the upper half of the building, while the lowest part is mainly affected by water capillary owing to the presence of soil on the left side and of an external well in the right side. Furthermore, the level immediately under the gun embrasures must be better investigated because of the anomalous distribution of water, declared by the blue and green areas that start from this ideal line
Figure 30 shows the water distribution inside the external facade of the Royal Prince Battery obtained merging the several pictures recorded in the same weather conditions: the distribution of the blue areas (corresponding to the coldest and wet ones) clearly shows that water preferably comes from the roofing and that distributes into the masonry according to its texture and conservation history. Indeed, all gargoyles are water saturated, while the upper left corner is partly isolated from the fortress by a fissure or restoration mortar, which needs to be better investigated. Furthermore, the concentration of water above the first level of the embrasures confirms that water deeply penetrates the vaults affecting the stability of the building.

Costantino Meucci

Figure 1. Scaffolding supporting one of the Coidavid vaults

Figure 2. The trusses supporting the vault are strong enough to support the weight of the detached part of ceiling.

Figure 3. Wooden frames are still weather exposed and risk to damage seriously.

Figure 4. The new wooden planks connect the walls of the adjacent rooms increasing the stability of the building.

Figure 5. Fissures affecting the walls of the Coidavid Battery in the unsupported chambers

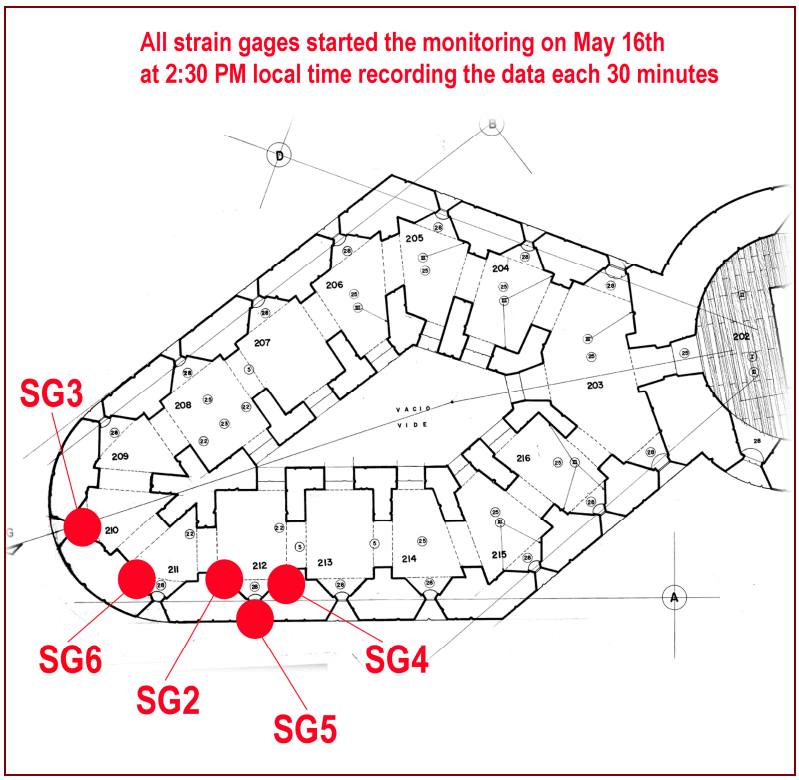


Figure 6. Location of the probes to carry out the monitoring of the fissures

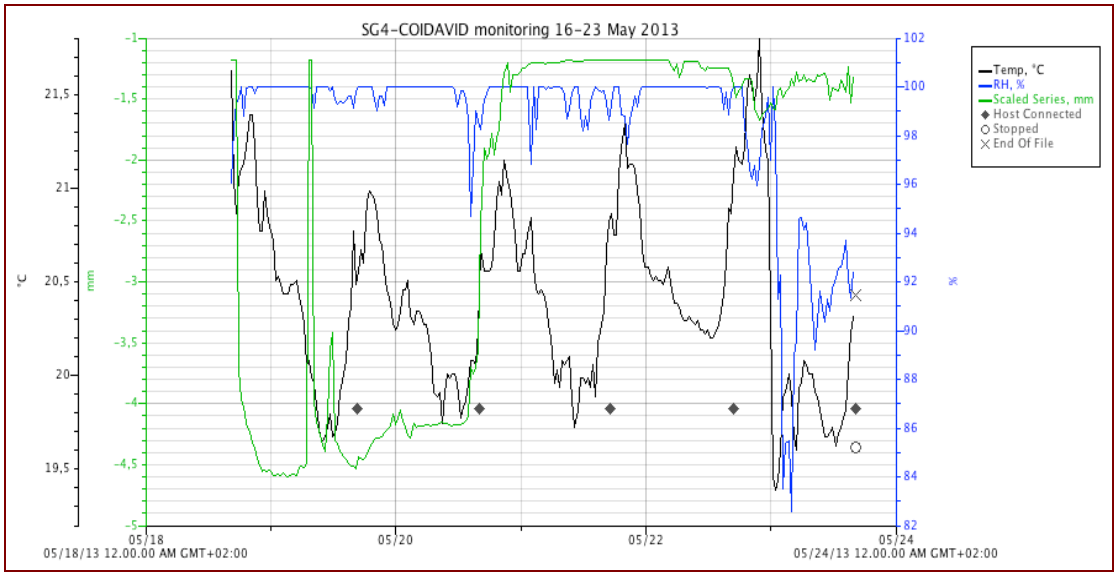


Figure 7. Graph of the monitoring in SG4 location showing the variability in the deformations of the fissure (green line)

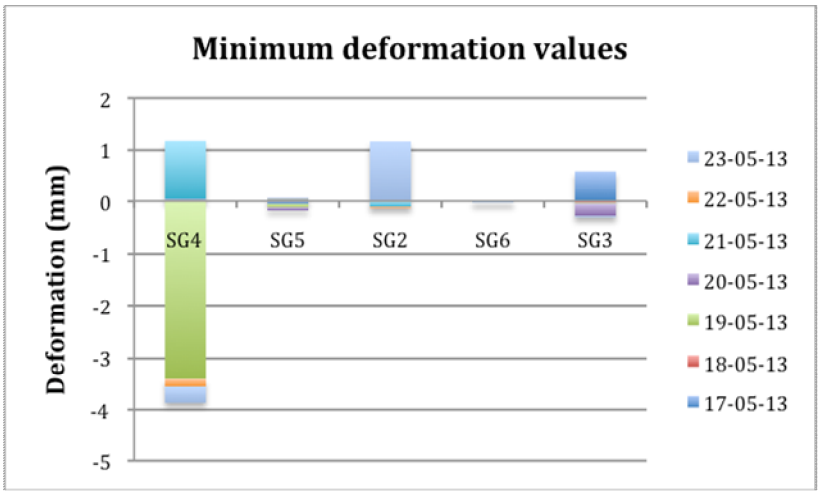


Figure 8. Cumulative negative deformation of the monitored fissures due to compression

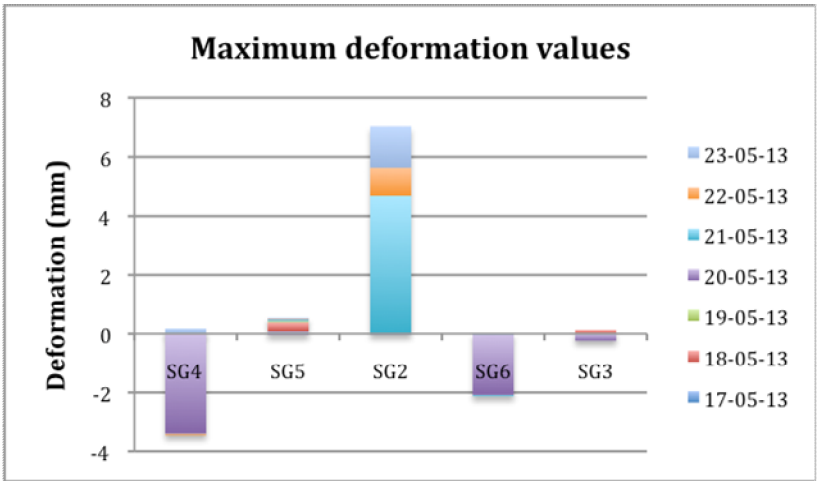


Figure 9. Cumulative positive deformation of the monitored fissures due to expansion

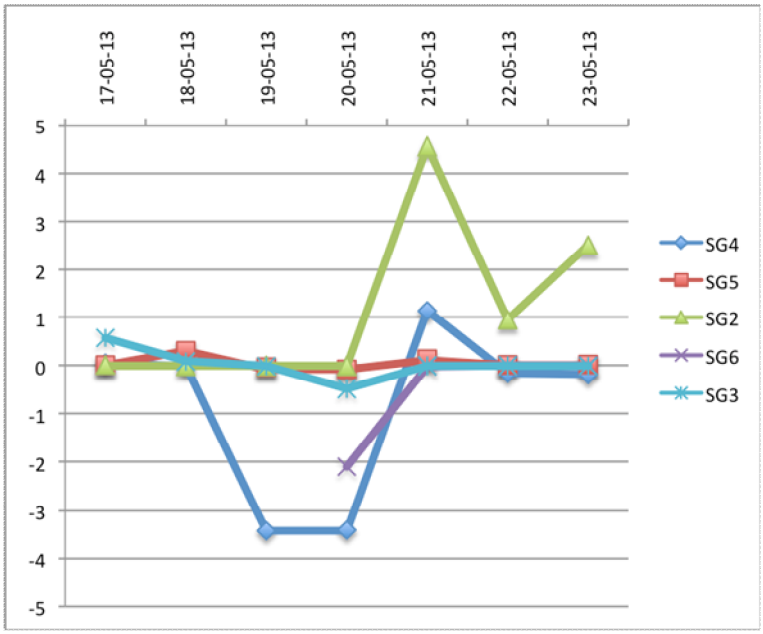


Figure 10. Absolute deformation trend in the monitoring time

Figure 11. Misalignment of the wall at the edge of the Coidavid Battery due to compression

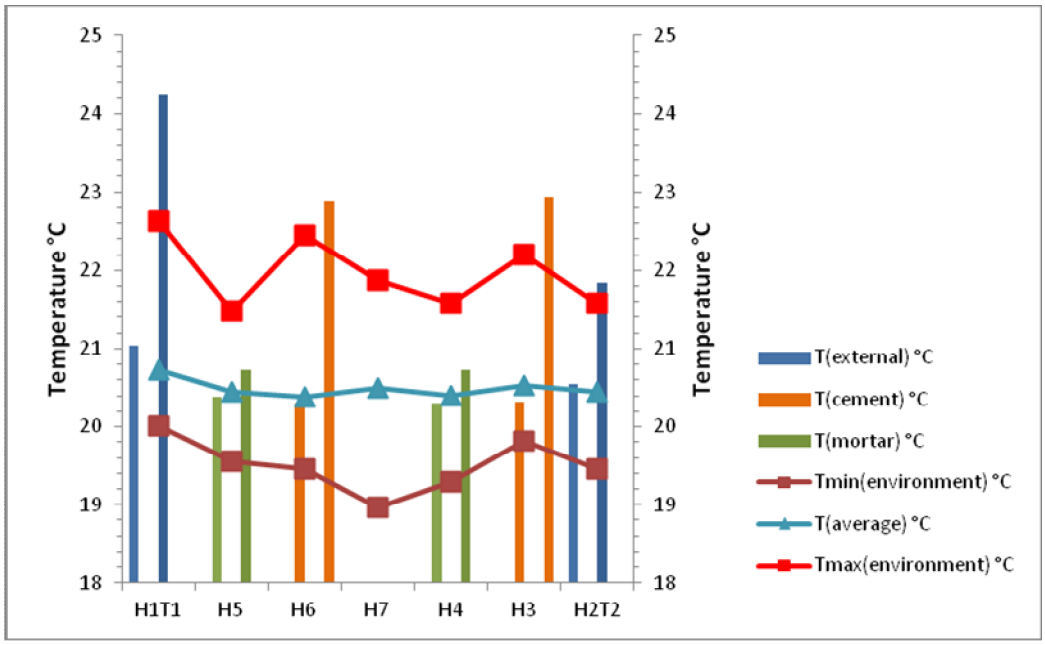
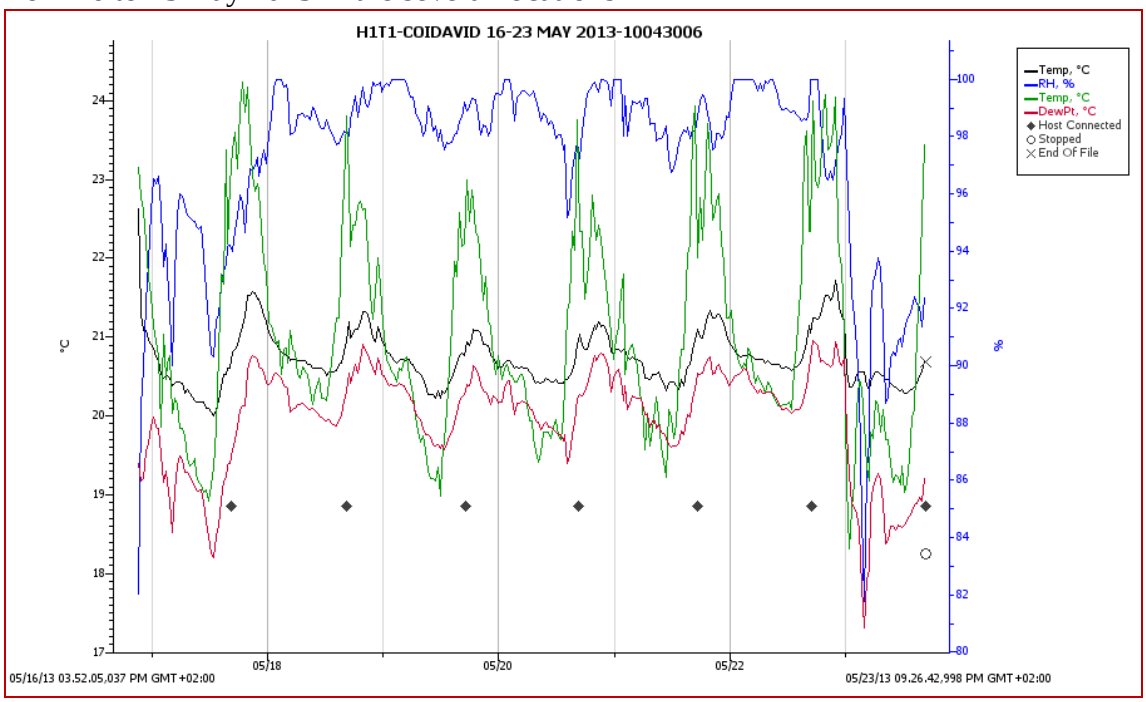


Figure 12.Comparison among the Temperature data collected in the Coidavid Battery in the period 16-23 May 2013

Figure 13a÷g. Charts of the microclimate within chamber 3L of the Coidavid Battery from 16 to 23 may 2013 in the several locations



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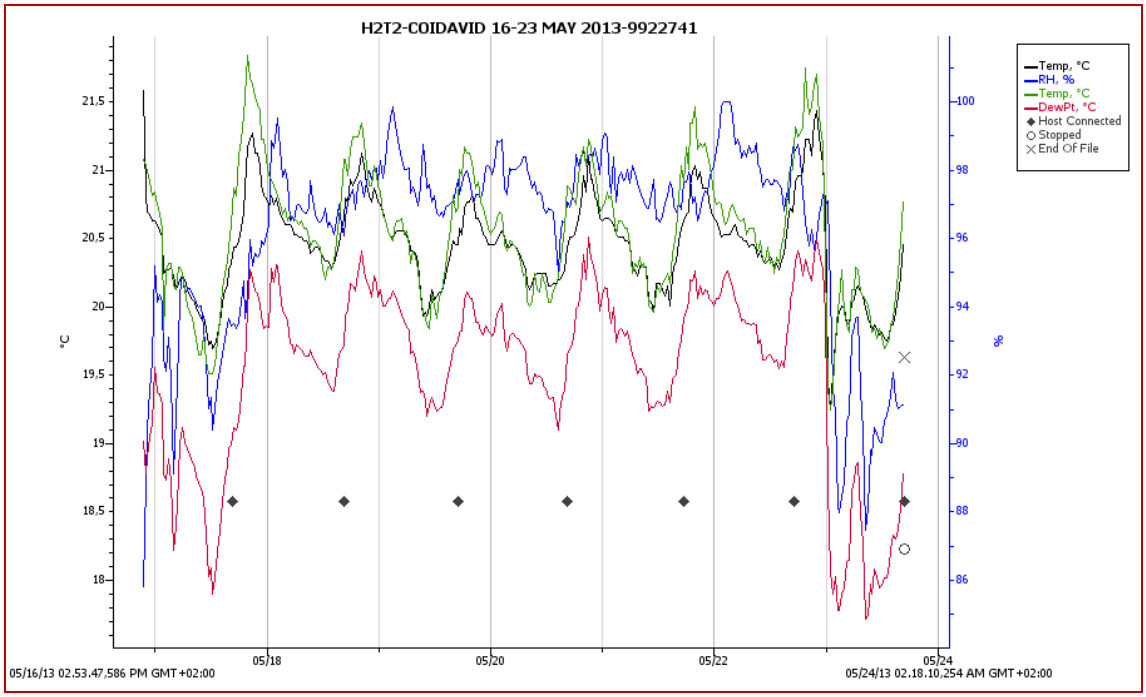
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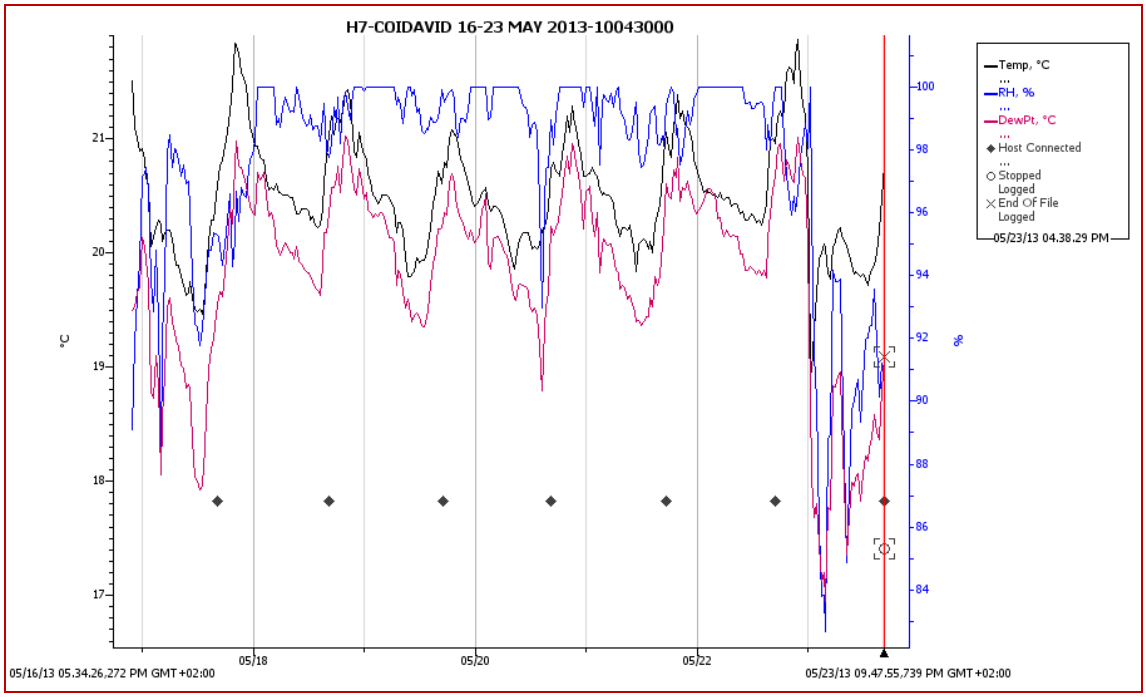
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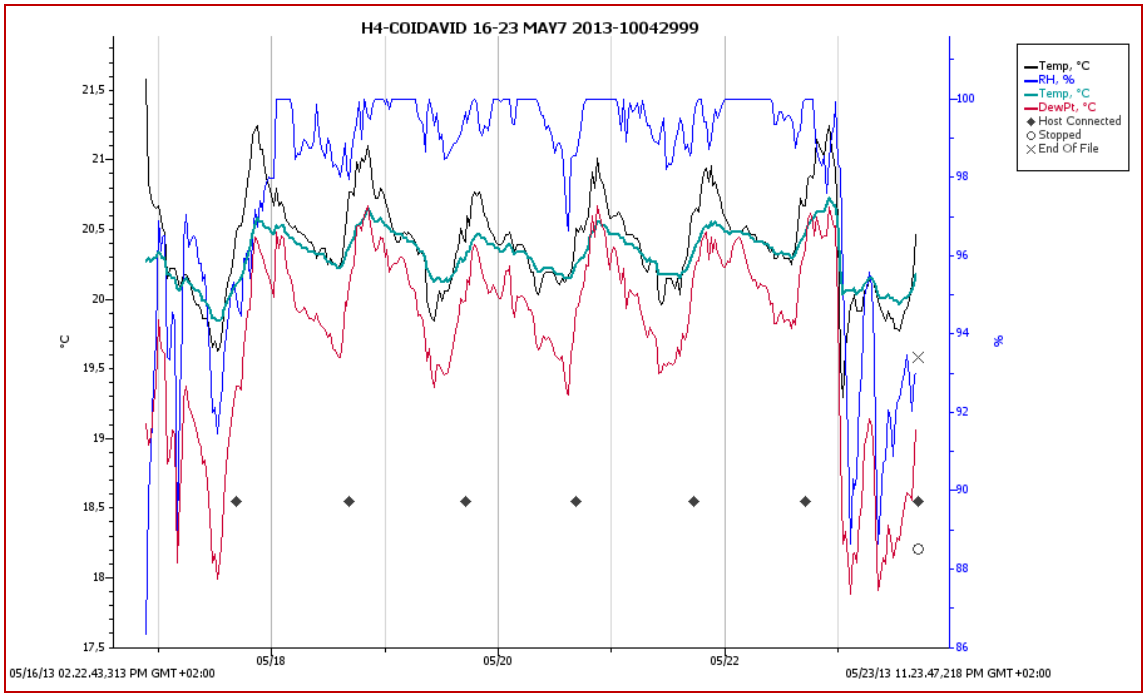
13c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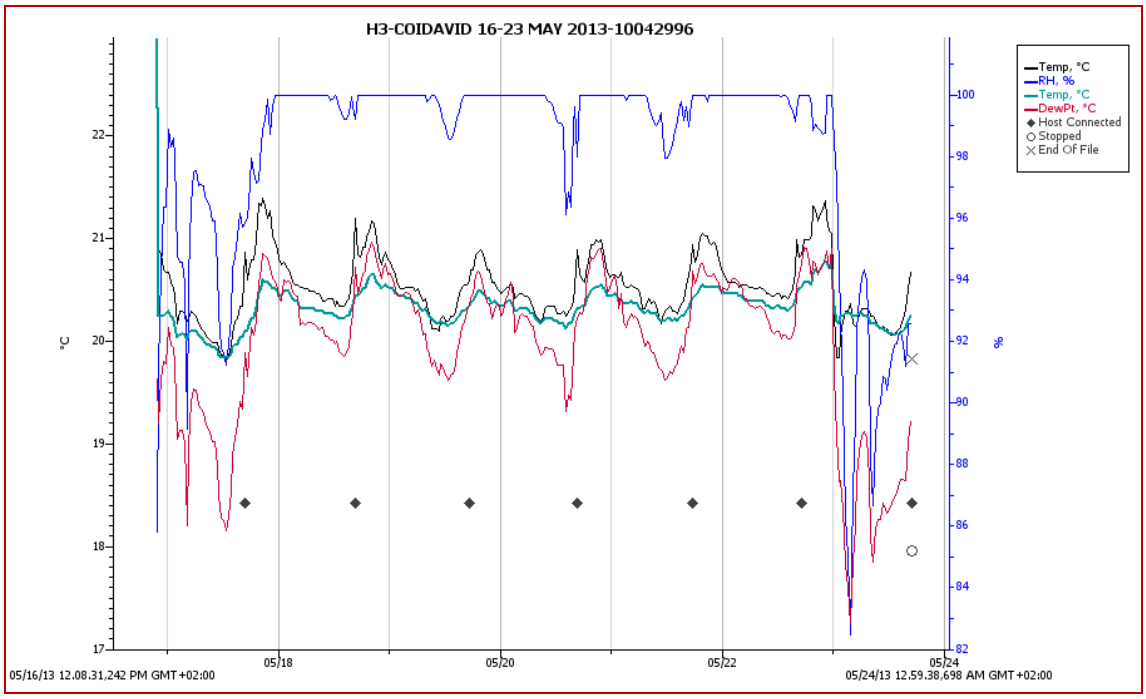
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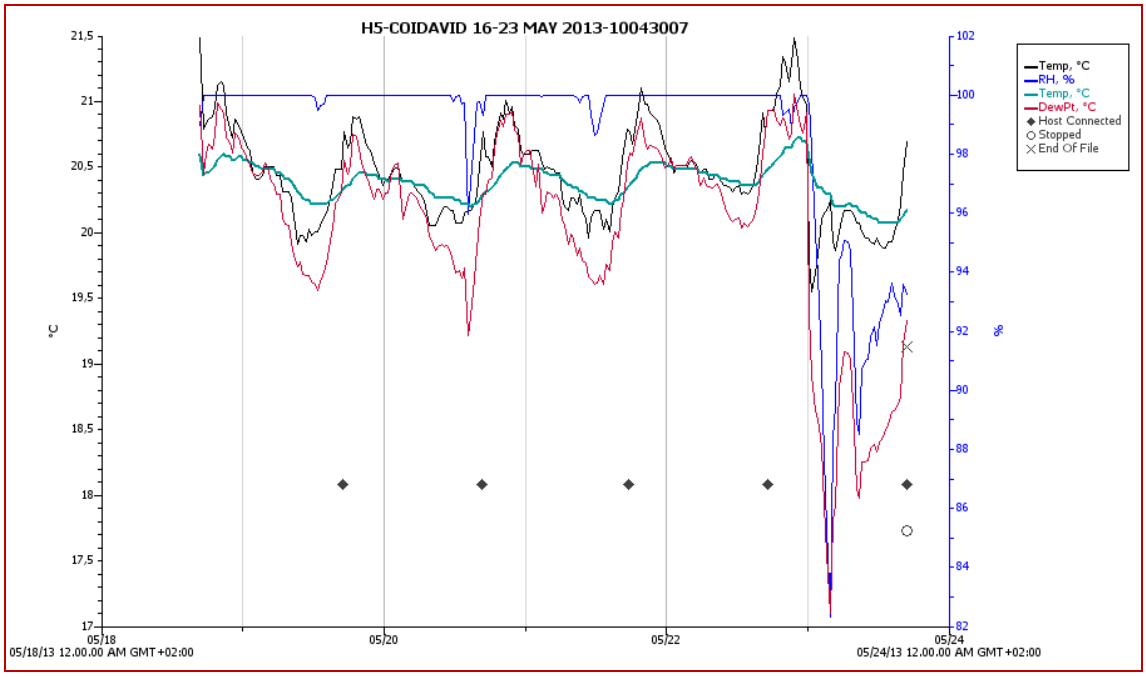
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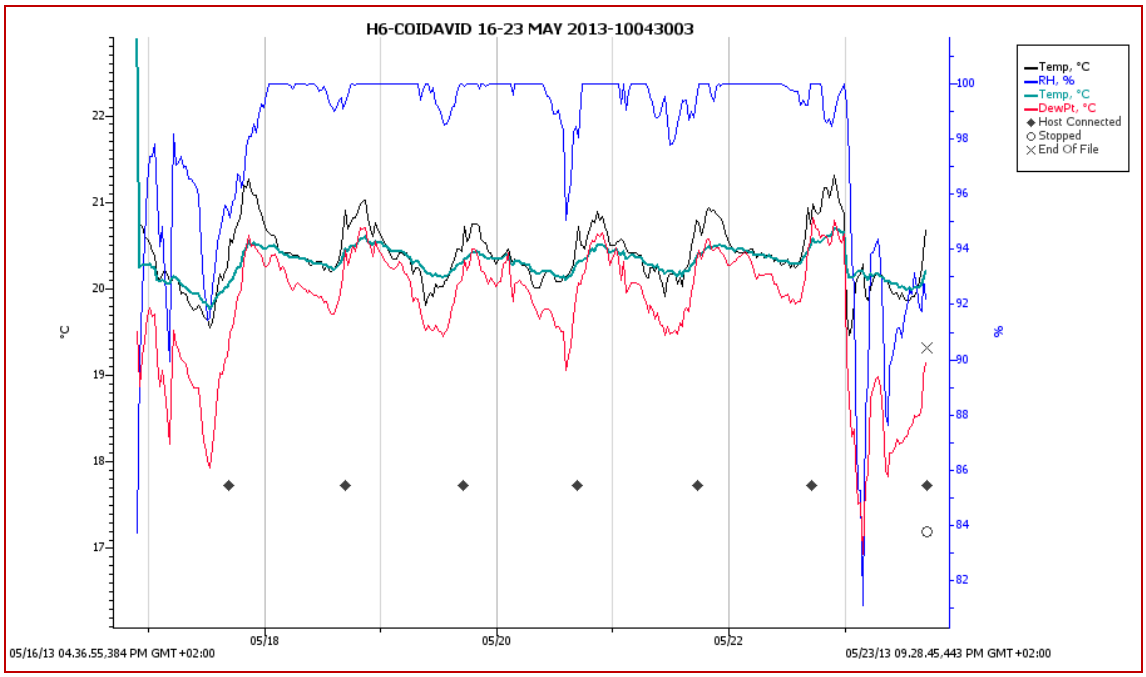
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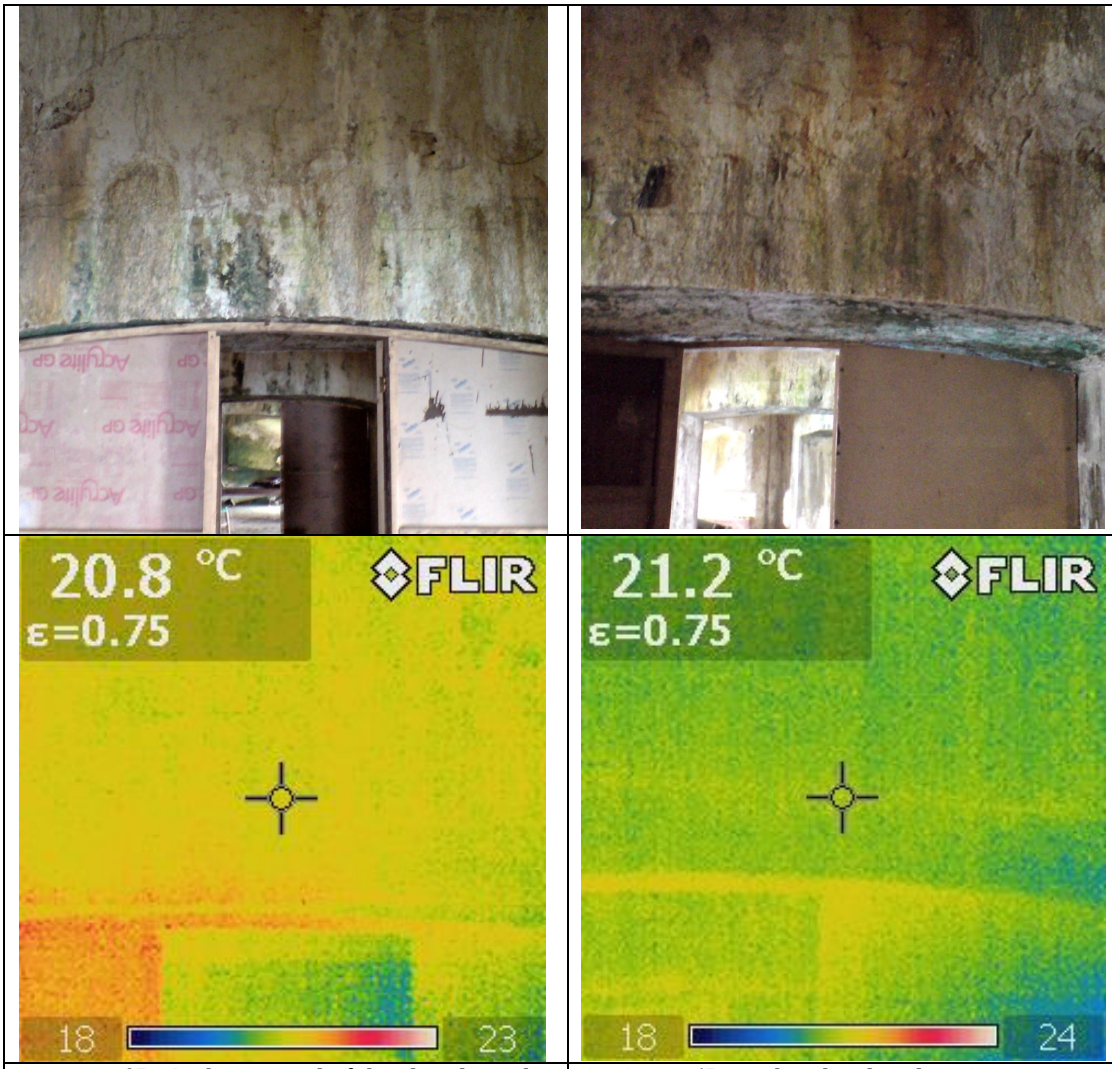


Set 2L→ 3L. At the external of the closed set, the architrave and the wall are dry and warm.	Set 3L → 4L. Within the closed set 3L water concentrates both on the restoration architrave made of concrete, and on the plaster covering the masonry.

Figure 14. Comparison of the FLIR images outside and inside set 3L

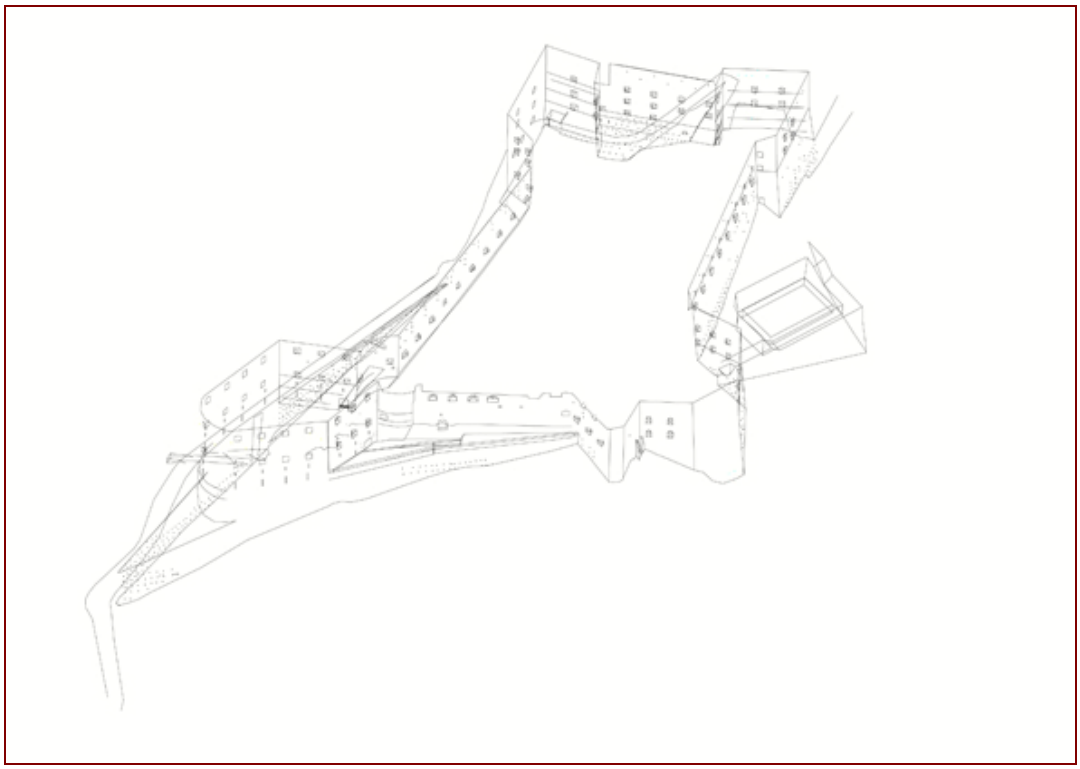


Figure 15. 3D isometric view (sky-line) of the Citadel from Northeast side

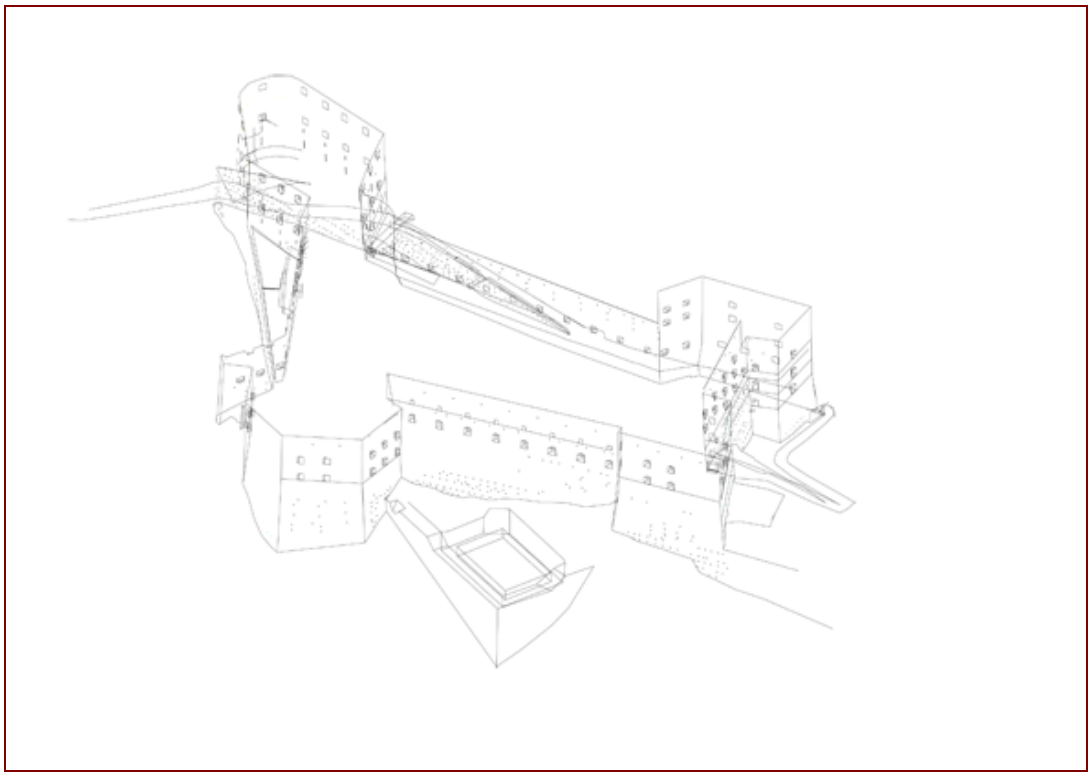


Figure 16. 3D isometric view (sky-line) of the Citadel from Northwest side

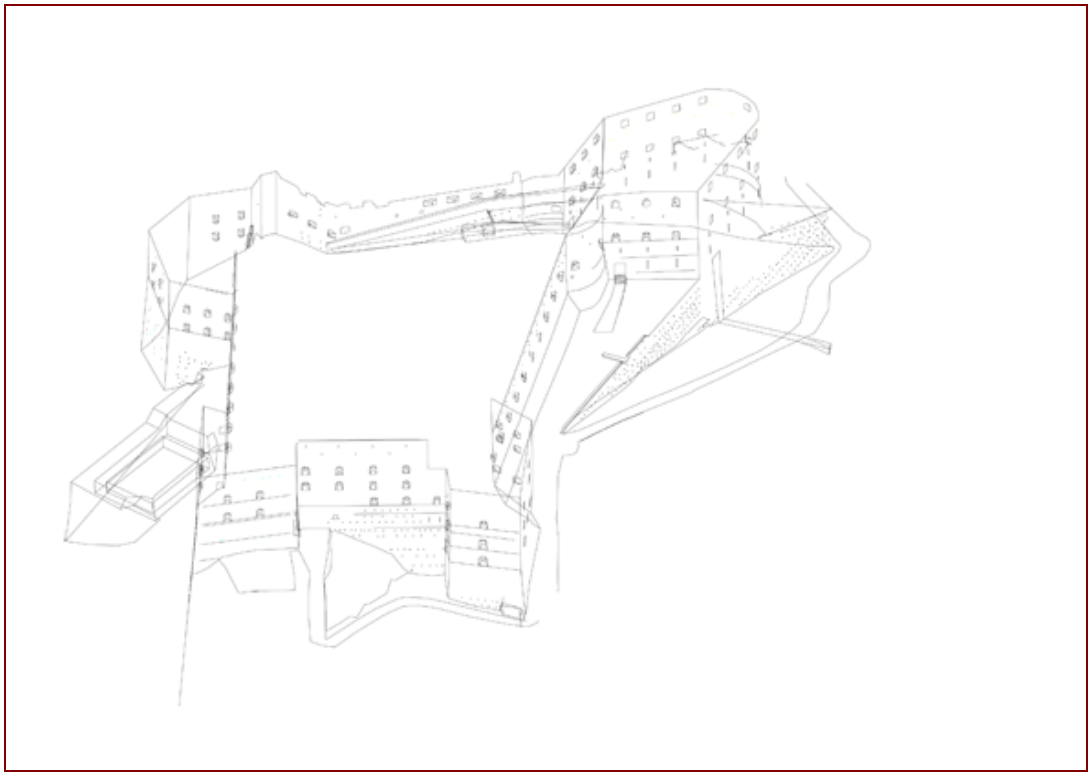


Figure 17. 3D isometric view (sky-line) of the Citadel from Southwest side

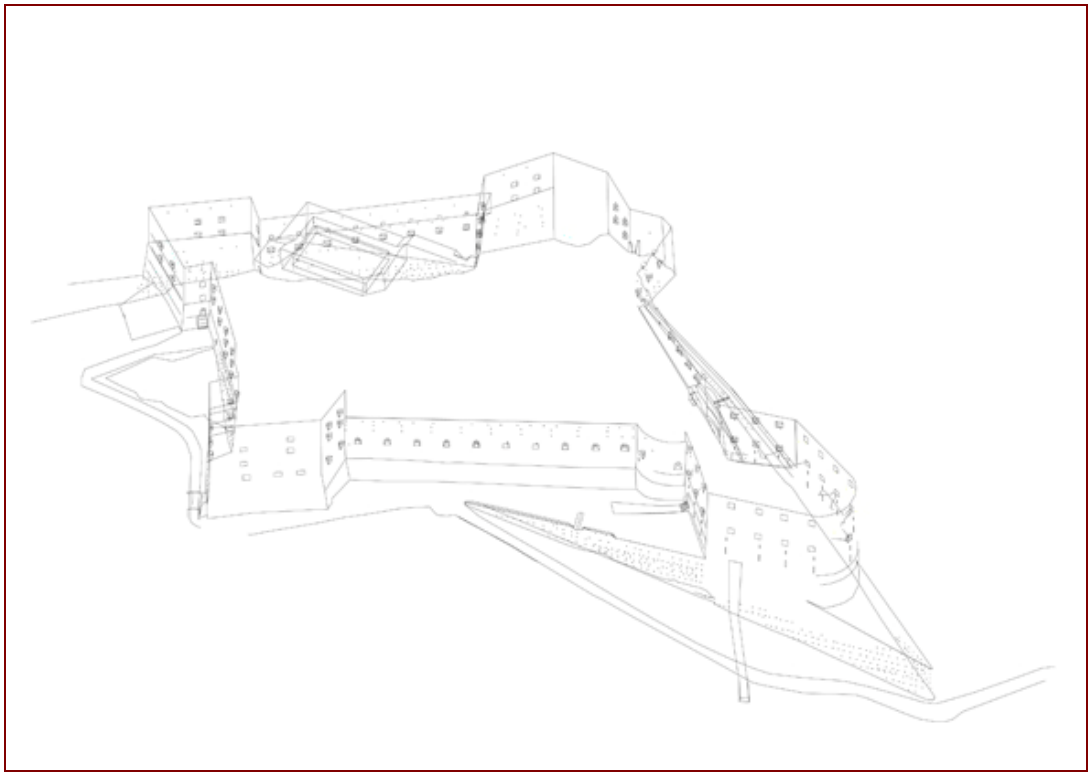


Figure 18. 3D isometric view (sky-line) of the Citadel from Southeast side

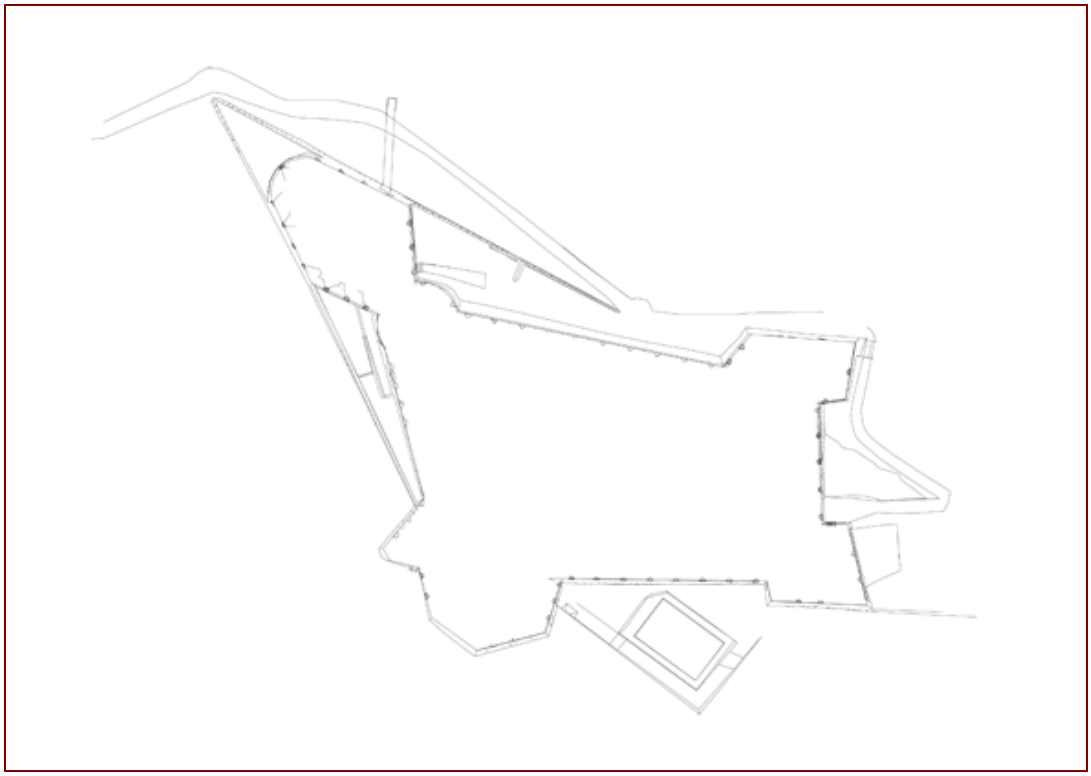


Figure 19. Plan of the Citadel from 3D sky-line.

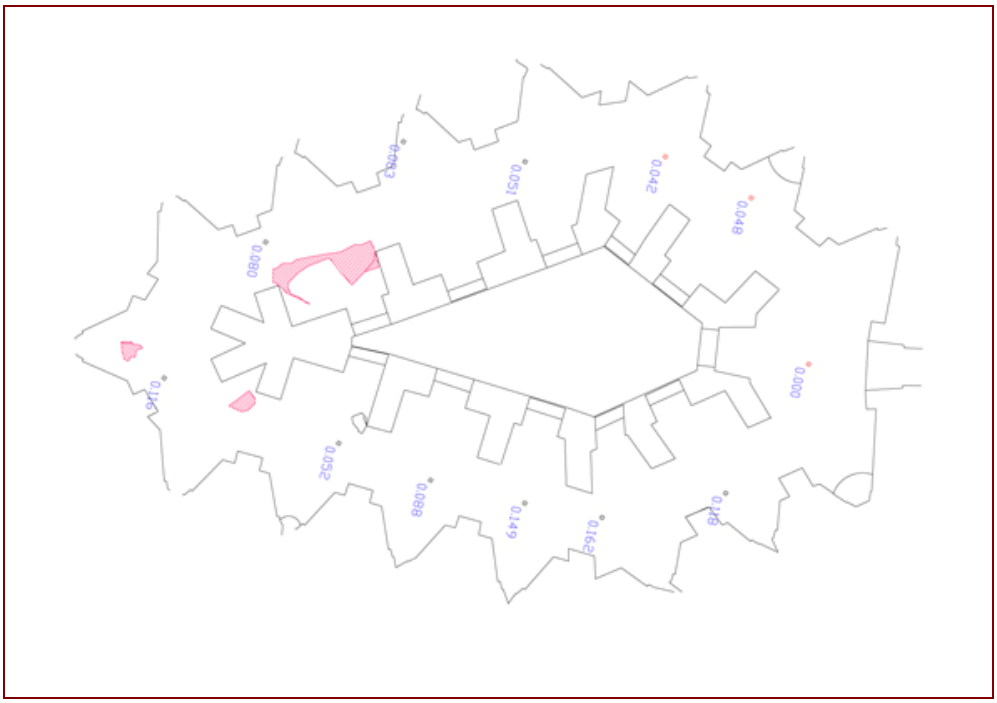


Figure 20. Plan of the third level of the Coidavid Battery

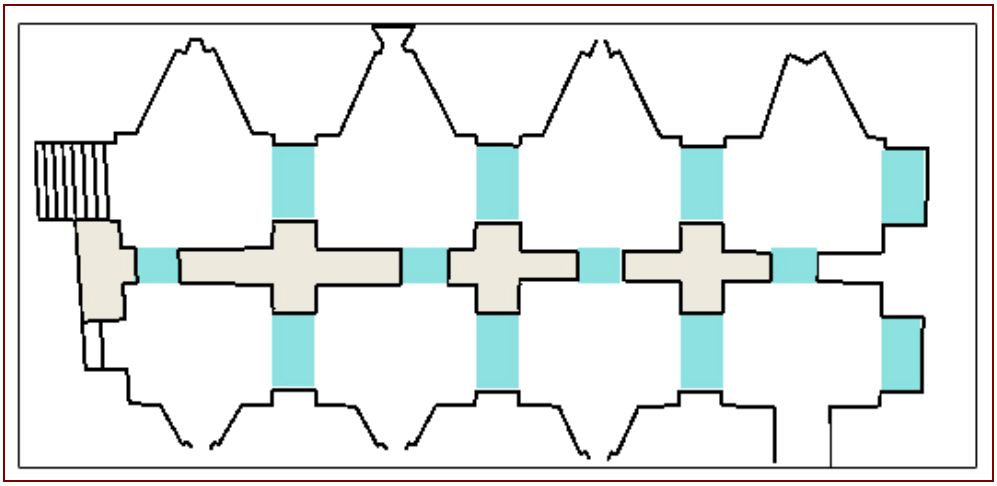


Figure 21. Plan of the upper level of the Queen Battery

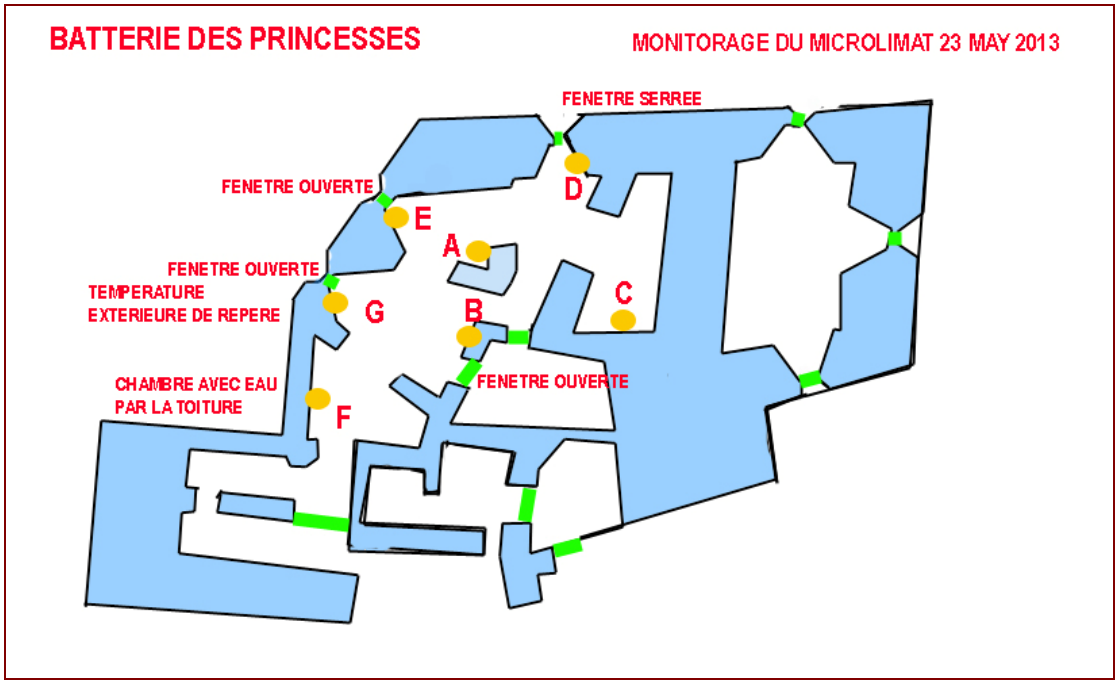
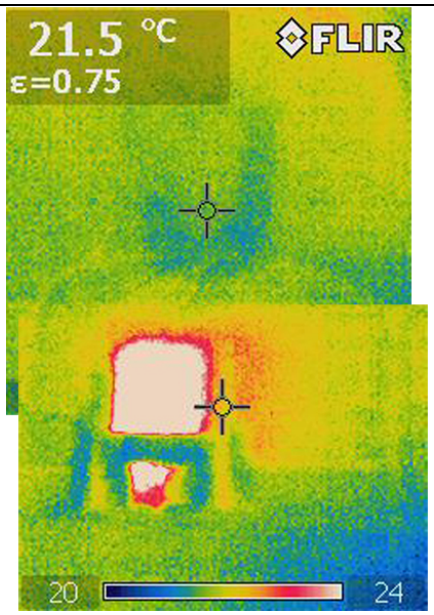
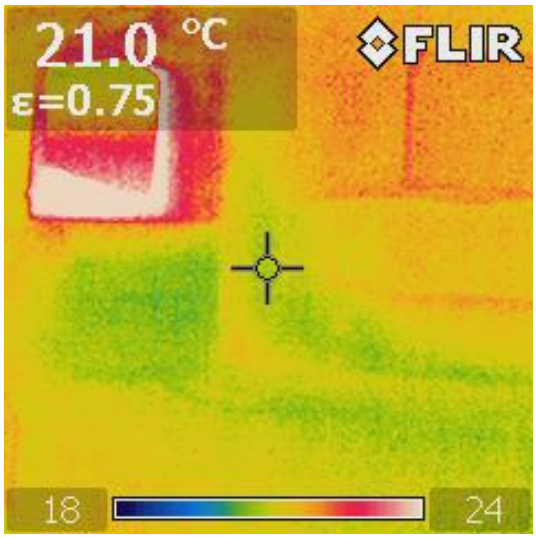


Figure 22. Location of the microclimate probes within the Princess Battery





Room D. Water stagnation on the floor causes capillary at the bottom of the walls, while rainwater filters from the roofing into the vault of the embrasure.	Room G. Water stagnation on the floor concentrates at the bottom of the walls where biological patinas growth

Figure 23. Within the Princess Battery water affects the masonry both because of the capillary from the floor, and the intrusion from the roofing

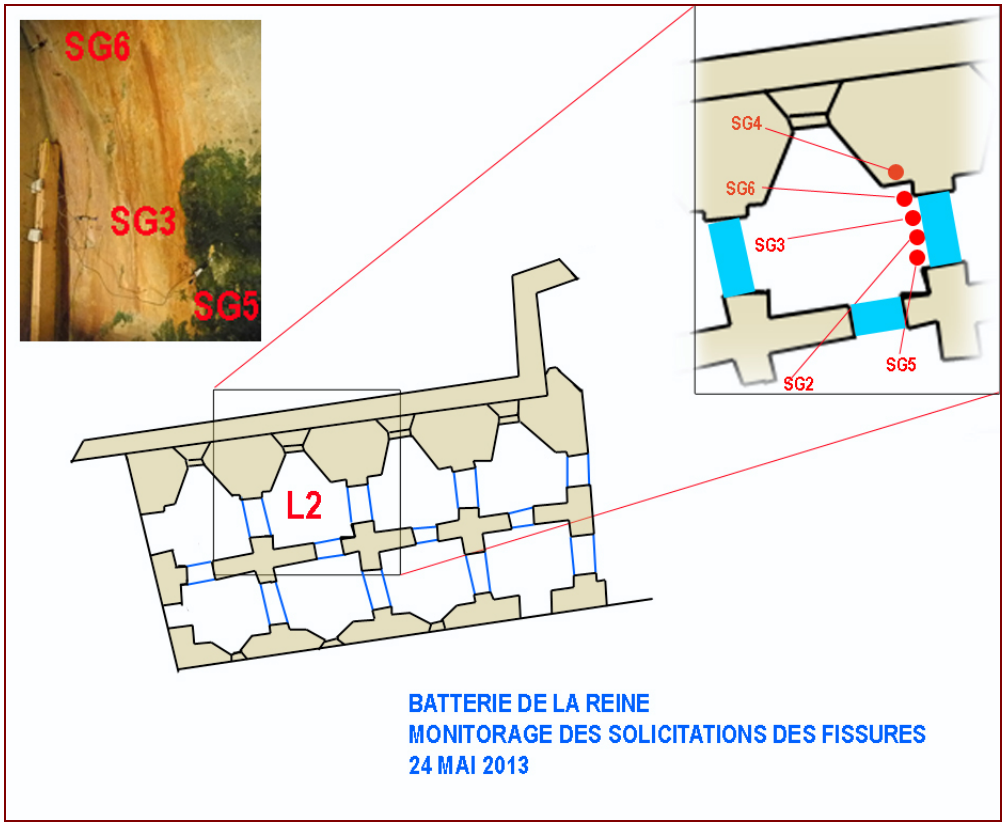


Figure 24. Location of the deformation monitoring system in the Queen Battery

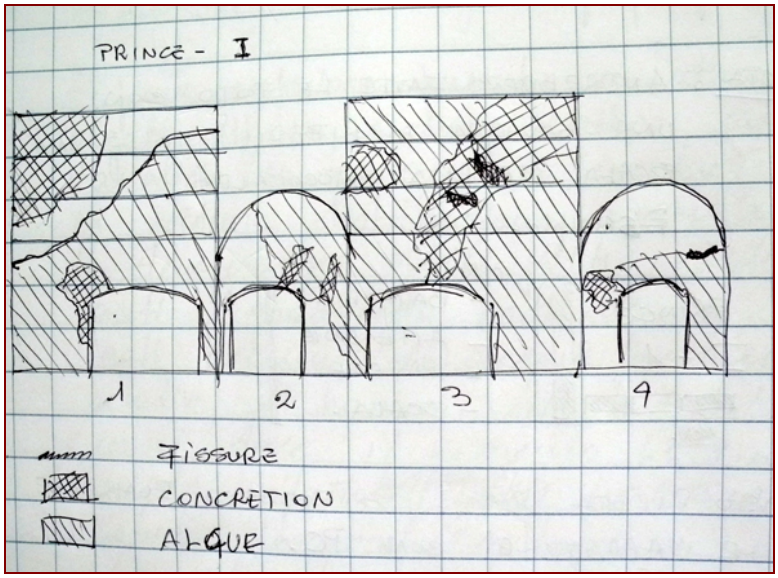


Figure 25. Example of sketch representing the distribution of typical damages on the walls

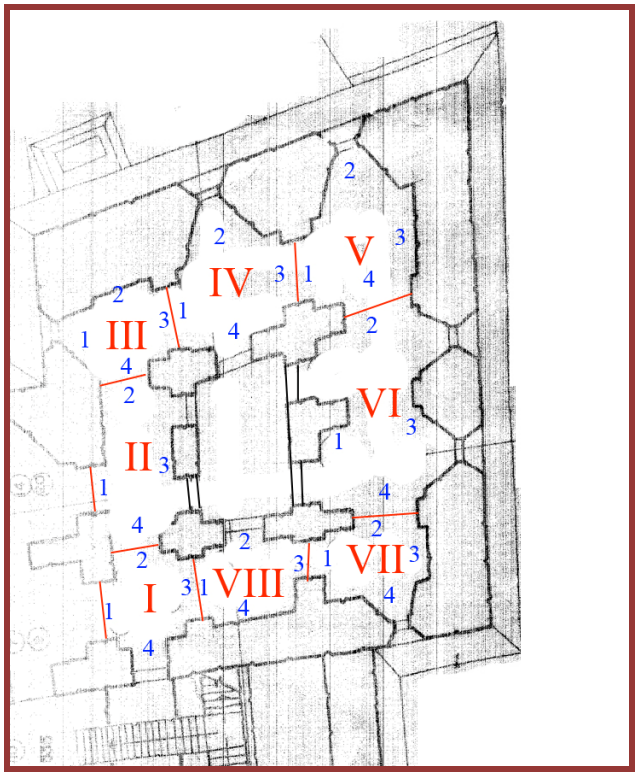


Figure 26. Conventional labeling of the rooms and the walls within the Royal Prince Battery

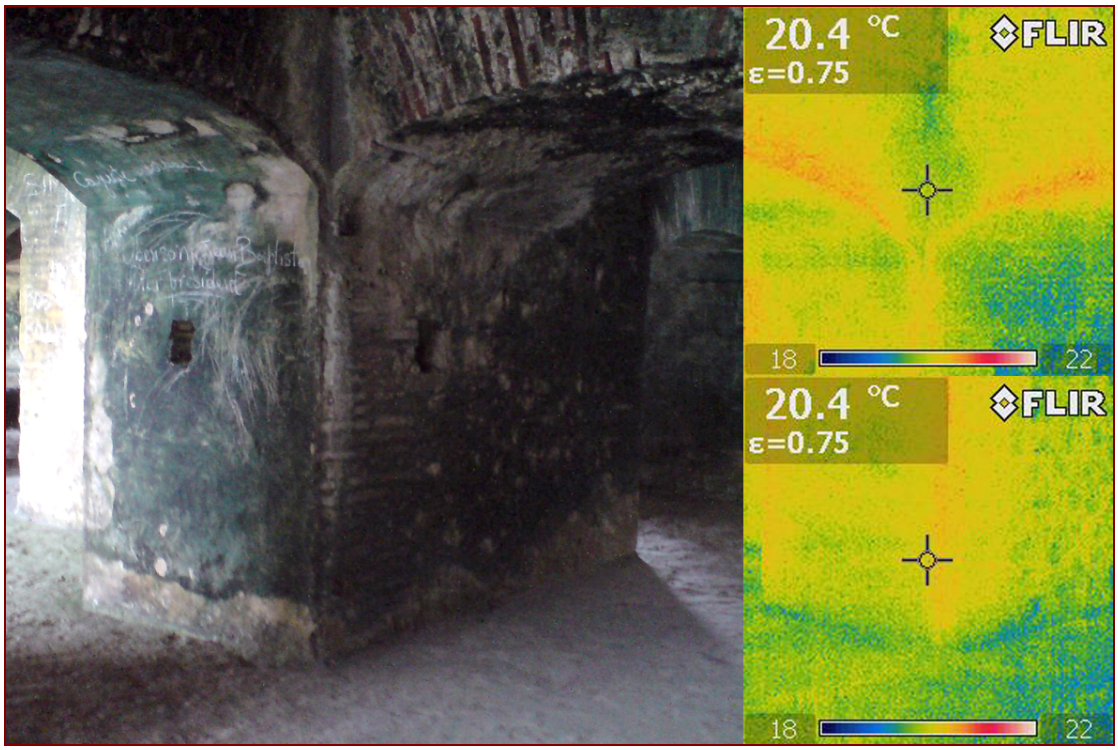


Figure 27. Example of IR investigation of damaged masonry within the Royal Prince Battery.

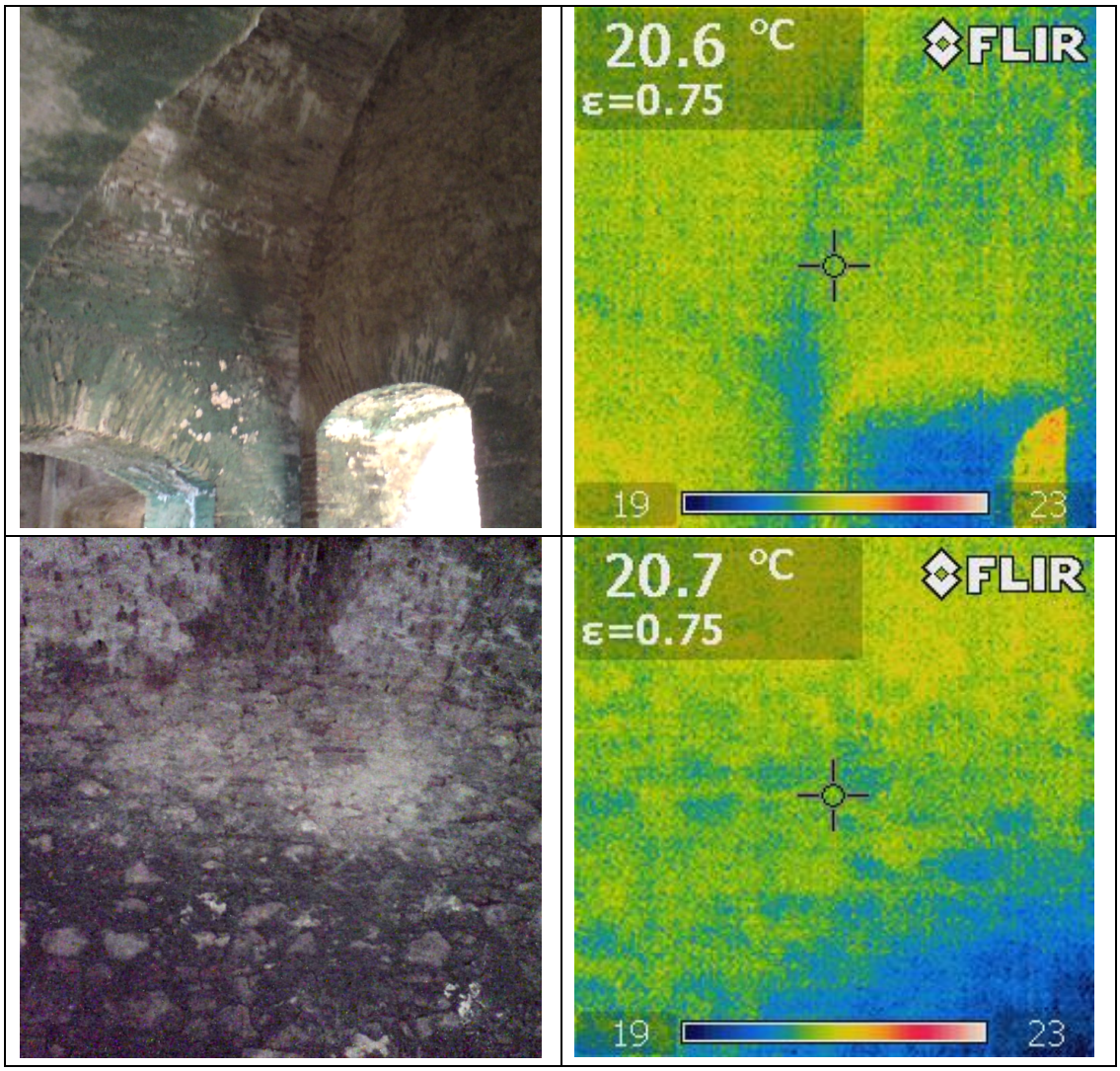


Figure 28. Royal Prince Battery, Room II,2-3. The vault and the wall exposed to the court are water saturated, as well as the arch of the window. Analyzing the wall 3 evidently appears that water preferably concentrates in correspondence of the stones, defining the texture of the masonry.

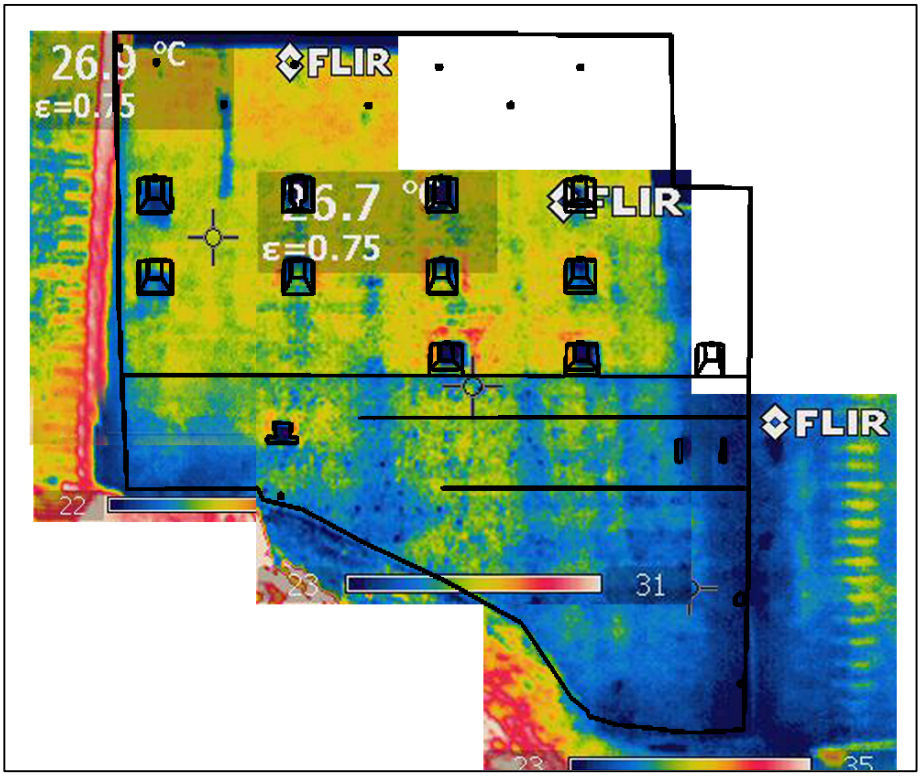


Figure 29. Integrated representation of water distribution into the external masonry of the Queen Battery

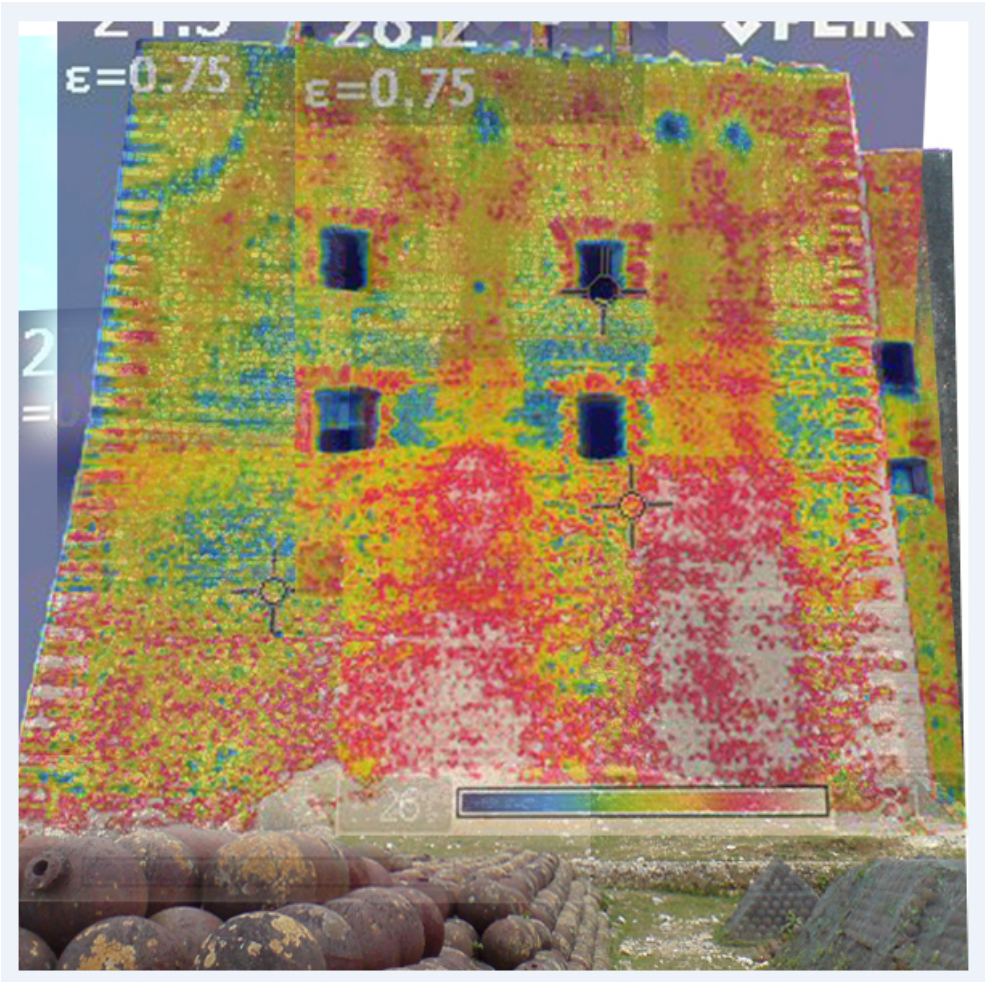
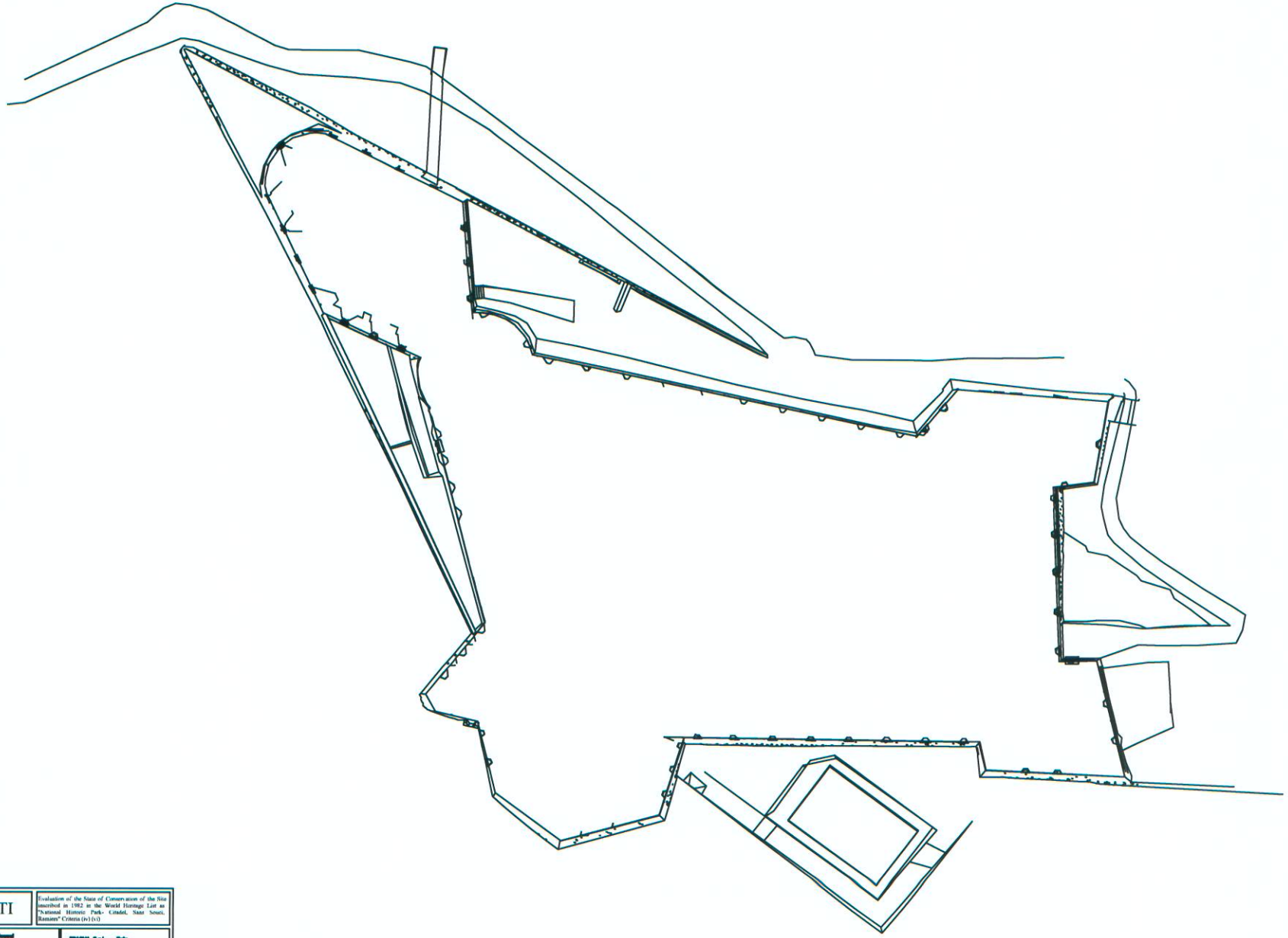


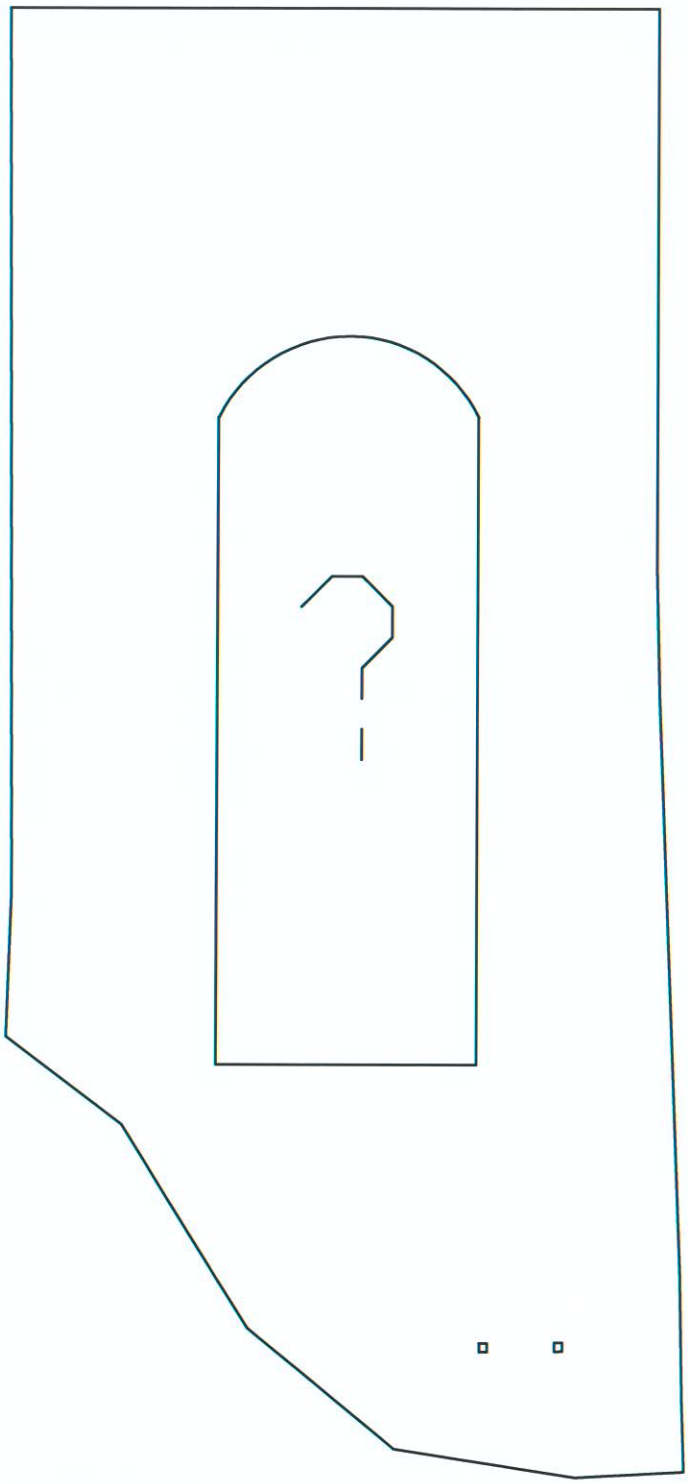
Figure 30. External facade of the Royal Prince Battery showing the distribution of water (blue and green areas) inside the masonry

Table 1. Microclimate monitoring data in the Coidavid Battery in the period 16÷23 May 2013

	Location	H1T1	H2T2	H7	H4	H3	H5	H6
Maximum Values	T(external) °C	24.24	21.84					
	T(environment) °C	22.63	21.58	21.87	21.58	22.20	21.49	22.44
	T(mortar) °C				20.72		20.72	
	T(cement) °C					22.94		22.90
	RH%	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Dew Point °C	20.95	20.51	21.02	20.68	20.97	21.06	20.82
Minimum Values	T(external) °C	18.32	19.25					
	T(environment) °C	20.01	19.25	18.96	19.29	19.82	19.56	19.46
	T(mortar) °C				19.84		20.08	
	T(cement) °C					19.84		19.77
	RH%	81.76	85.80	82.65	86.33	82.47	82.31	81.09
	Dew Point °C	17.31	17.72	16.95	17.88	17.25	17.10	16.90
Average Values	T(external) °C	21.03	20.55					
	T(environment) °C	20.73	20.45	20.50	20.41	20.53	20.46	20.39
	T(mortar) °C				20.31		20.38	
	T(cement) °C					20.33		20.31
	RH%	97.25	96.23	97.71	97.93	98.21	98.80	98.08
	Dew Point °C	19.97	19.52	19.83	19.75	19.97	20.06	19.79



HAITI	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)
Dr. Gabriellino Massari Consultant – Italy	PRASSA S.r.l. – Italy
CITADEL	GENERAL PLAN
Project: [illegible]	Drawings: [illegible]
DATE: May 2010	SCALE: 1:500



HAITI	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)
Dr. Costantino Meucci Consultant – Italy	PRAGMA S.r.l. – Italy
CITADEL	BATTERIE DU GRAND-BOUCAN - Front NW
Projects Costantino Meucci	Drawings Massimo Sabatini
DATE: May 2013	SCALE: 1:50

0 1 5 m.