DESTRUCTION, RECONSTRUCTION, RESTORATION: FROM THE "PROJECT OF KNOWLEDGE" TO MONUMENTS' CULTURALAND MATERIAL RETURN TO COMMUNITIES: STUDY CASES

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Abstract. The restoration and the care of monuments damaged by people and time are based on a cultural path rooted in the principles of conservation and on advanced technical knowledge that includes constantly evolving applications. No restoration project can begin and make sense without careful historical research, without direct verification of archive documents, without the ability to read the so-called "direct documents". A case study is the restoration of the Fortress of Arezzo, Italy, a XVth century fortification. A second case is that of an analysis and restoration process of a long stretch ofancient walls in the historic city of Suzhou in China.

Keywords: Restoration, last generation survey, diagnostics of monuments, dialogue antique/contemporary architecture, destruction/reconstruction, conservation of monuments

In the restoration process it is becoming increasingly clear that there is a need to launch an extensive, careful, multidisciplinary "knowledge project" based on the technical expertise and sensitivity of architects. This "knowledge project" becomes an "integrated knowledge path" through the crossing of data coming from increasingly refined and extraordinarily useful technologies such as:

- The skilful use of laser scanning technology, both for very high precision of the two- and three-dimensional knowledge of the monuments to be restored and for diagnostic aspects.
- Image diagnostics using thermography for effective "restoration of the invisible".
- Acquisitions with georadar and geoelectric instruments for knowledge of the seabed data with latest-generation three-dimensional tomography.
- The physical-chemical analysis of materials with high-level instrumentation.

The "path of knowledge" constitutes the basis of a process that then requires both technical skills andculture with reference to specialised restorations and allow the transmission of the historic material to the future, as well as minimal and respectful new functions and "compatible inventions". This willmake possible to extend the life of the monuments themselves as they are useful, travelled, animatedby shared activities, making us feel all the past, the wounds caused by people and time and a possiblefuture, indeed bright and unpredictable. The considerations made up to now can be exemplified in two restoration projects united by the same coordination and by a shared cultural and technical path.

THE RESTORATION OF THE XV CENTURY AREZZO FORTRESS

Historical notes: sixteenth-century events and notes on pre-existing buildingsThe Fortress of Arezzo closes the city's defensive circuit towards the north-east, dominating the whole Arezzo area fromits bastions (Fig.1).

It was built on a site previously occupied by pre-Roman and Roman buildings and, above all, by the medieval fortified citadelconsisting of palaces, towers and a dense and rich fabric. In October 1502, at the behest of the Medici family, Giuliano and Antonio "the Elder" da Sangallo were sent to Arezzo, where they outlined a project to reorganize the entire building of the Citadel.

The first project was conducted around the years 1506-1508. The present Fortress preserves two bastions from this first construction phase: the one called della Chiesa and the Soccorso bastion, as well as the connecting curtain wall between them. The Fortress was put to the test during the prolonged siege it suffered at the hands the people of Arezzo from November 1529 to May of the following year. The reconstructionthen passed into the hands of Antonio da Sangallo the Younger– Giuliano's and Antonio the Elder'snephew– who was sent to Arezzo by the Florentine Republic in 1534. The medieval Citadel was completely demolished in order to reuse the materials and leave room for cannon fire. In January 1540 works were finished with the construction of the other three bastions the Belvedere and Diacciaia, with the Spina in the middle.

Figure 1. The City of Arezzo and the XVI Century Fortress

Decadence and progressive disarmament of the Fortress. During the seventeenth and eighteenth centuries the city enjoyed a period of great peace. The decision on the ownership of the Grand Duchy was taken in Vienna back in 1735: after the end of the War of the Polish Succession Poland was awarded the Duchy of Lorraineand European diplomats allotted the future Tuscan heritage to the reigning but ousted Duke of Lorraine. With the rule of the Lorraines,Colonel Odoardo Warren (Fig. 2) was entrusted with the task of making the fort efficient again but the wish didn't materialize sincevarious rooms inside the Fortress were used as deposits.

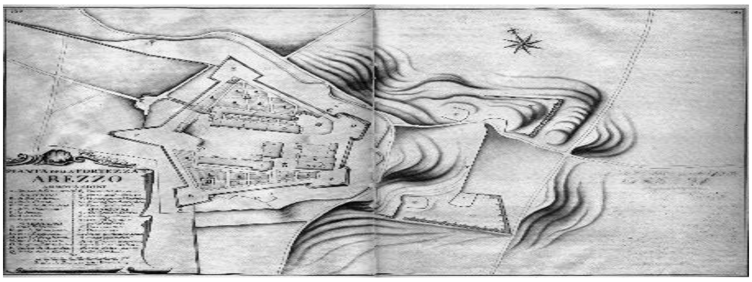


Figure 2. The Fortress in a XVIII Century map by O. Warren

From the destruction by Napoleonic troops to twentieth-century transformations. In 1791 Ferdinand III (1769-1824) succeeded his father Peter Leopold. Worried by Napoleon's expansionist aims, in November 1798, just 15 years after the sale of the Fortress, Ferdinand retook possession of the fortress. In May 1799 the rebellion against the French troops occupying the entire region was ignited. Nevertheless, in October 1800, Napoleon's troops entered the city devastating thebuilding. As a punitive gesture, on 26 October the Belvedere bastion was mined and literally split into two parts, and the same happened to the Soccorso bastion. In November of the same year the French demolished all the buildings inside the Fortress. The twentieth-century chronicles referring tothe Fortress of Arezzo testify to a conspicuous silence and indifference of the citizens, scholars and experts. This lack of studies and restoration works are at the origin of the decision to place a reinforcedconcrete water tank in the center of the Fortress, a square block with sides measuring about 40 meters,partially buried at a depth of around eight meters. The excavated soil was scattered inside the Fortress itself, raising the original height of the parade ground by about four meters.

The first restoration phase of the Fortezza. The restoration of the Fortezza's external facings, carried out between 2008 and 2011, was an extraordinary application of stone restoration criteria and techniques (Fig. 3,4), starting from a surveycarried out with laser-scanner technology (Fig. 5,6) and a careful diagnostics program (Fig. 7,8,9).

Figure. 3, 4. The Fortress before the exterior walls restoration project

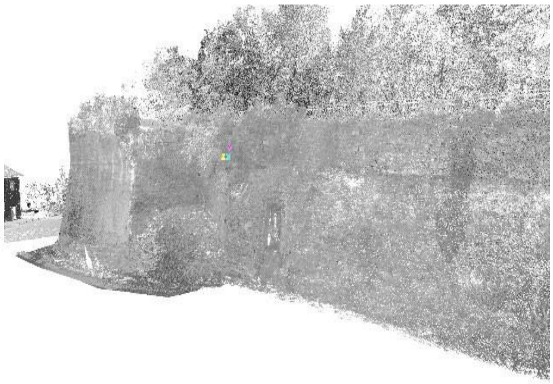


Figure 5, 6. The laser-scanner survey

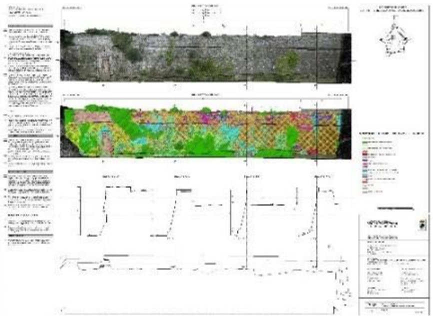


Figure 7.
The decay analysis and restoration project on ortophotos

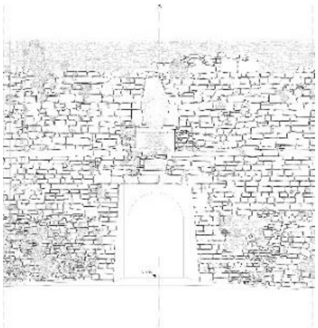


Figure 8.
Detail analysis of the materials

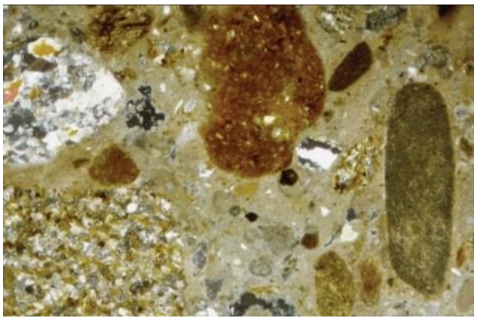


Figure 9.
Petrographic analysis conducted in the University Laboratory

The stages, and techniques can be summed up as follows:

- During the works preceding the actual restoration and building work unsafe parts were secured and stabilized, and parts that had detached from their support were put back in place.
- Physical, chemical and petrographic analyses were carried out to identify and test suitable products; samples of mortars were analyzed. Biological analyses were conducted to find bio- deteriogenics on stone samples in order to establish which actions and disinfection chemicals to use and how to apply the biocidal products. After sampling and evaluating the results, specific biocidal products were sprayed in cycles to eliminate the lower vegetation colonies consisting ofbacteria, algae and lichens.

- Cleaning operations were carried out: dry cleaning to eliminate particles, dust and guano deposits,removed with brushes; cleaning stable stone surfaces with low pressure de-ionised water with water jets with rotating heads (Fig. 10) selective cleaning of stone surfaces in the areas where deposits were thicker, more compact with distilled water and a saturated solution of ammonium carbonate (Fig. 11,12).

Figure 10.
Low pressure water cleaning of the walls

Figure 11.
Manual filling of cracks and joints

Figure 12.
Selective cleaning with ammonium carbonate

Specific consolidation work was carried out: consolidation of fragments, after pre-consolidating them with ethyl silicate, with epoxy resin and by inserting fiberglass pins (Fig.13) consolidating fractures by inserting stainless steel pins and injecting pressurized fluid epoxy resin; indenting masonry to mend specific lesions with the same stone as the existing one, filled with a suitable mortar.

Figure 13. Consolidation with fiberglass bars

- Substantial work was carried out filling in deep cracks sealing the ridges and contours on the summit by casting or injecting mortars made of natural hydraulic lime and mason sand.
- To consolidate the overall surface of the wall, two coats of ethyl silicate were applied with a brush.
- As for consolidating and securing parts that had collapsed works were conducted on the disruptions caused in 1800 by mines detonated in the Belvedere, Chiesa and Soccorso bastions. Following specific pre-consolidation and consolidation operations, cores were made to allow the insertion of stainless steel bars on the entire length of the ramparts, placed horizontally and at a regular distance, and stainless steel rods grouted into the masonry obliquely to ensure structural continuity (Fig.14).

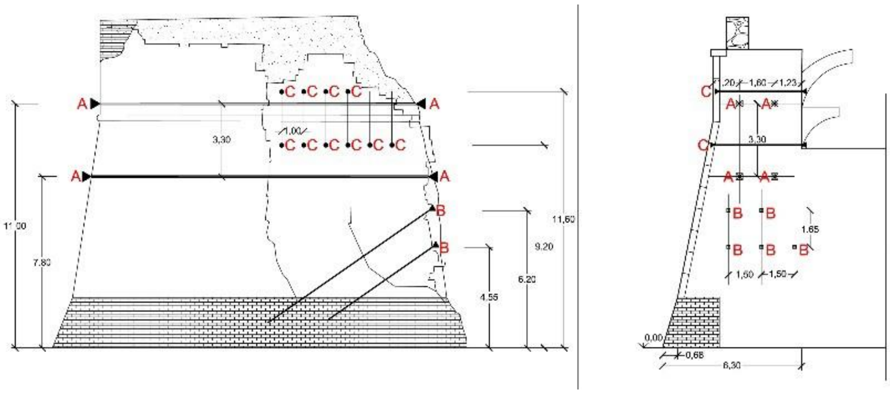


Figure 14.
Project of consolidation of the bastions with insertion of stainless steel bars

The second phase of the restoration of open spaces a
nd bastions in the Fortress.




Figure 15, 16, 17, 18. The Fortess after the restoration of the external walls and details (end of phase one)

Following the restoration work initially carried out by means of specialized works on the curtain walls,complex and delicate conservative operations have been conducted on the ramparts as well as the open spaces inside the Fortress (Fig. 19, 20).

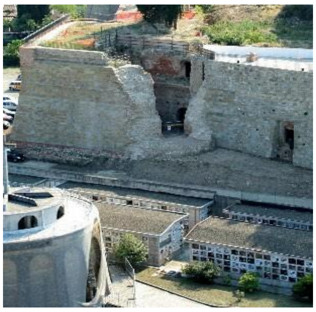



Figure 19, 20. The Fortess after the restoration of the external walls, aerial views (end of phase one)

This monument has now become a permanent place for an unexpected nemesis – a physical and mental space handed down to history. The second phase of the restorations started in 2012 and was recently concluded (Fig. 21, 22).

Figure 21, 22. Plan ad aerial view of the fortress after the overall restoration

The work was aimed at returning an extraordinary monument to the community, but also at creating a new cultural Center for Art exhibitions, shows, educational activities, learning spaces and knowledge sharing (Fig. 23).

Figure 23. Archaeological findings: the floor of a Roman house

The restored Bastions develop into a cultural mission On the one hand, therefore, the Fortress rooms inside the visible and measurable bastions had to be preserved in all their components, operating the necessary albeit rare structural reinforcementoperations, and maintaining each integral part in the single rooms as evidence of a building style andconcept of fortified spaces, as well as stopping the degradation without making renovations. The planned use required designing easily reversible and low-maintenance technological equipment. Functional needs, regulatory and comfort requirements that would let people enter and spend time inside the Fortress highlighted the need for interaction between pre-existing parts and new additions.Regarding the work carried out on the ramparts, the spatial system that typifies the cultural use of theFortress of Arezzo finds a particularly significant example in the Soccorso bastion on how to reorganize entrances and exits as well as the use of the building and its dedicated areas. This architectural addition establishes an unprecedented dialogue between ancient and recent architecturethrough the contemporary language of newly built heart-shaped portion of the bastion, which collapsed under Napoleonic mines in 1800. The Soccorso bastion is also a new entrance to the Fortress; the figurative re-composition of its geometry, without concealing the original loss of continuity, bridges the gap from a formal point of view and reverses the sense of traditional impenetrability that is typical of defensive buildings: the new curtain wall allows for controlled transparency at night as well as in daytime (Fig. 24, 25, 26).

Figure 24, 25, 26. The "Belvedere Bastion" destructed in 1800 by the Napoleon troops, reconstructed as a contemporary architectural addition referring to an historicized loss

Recent restoration work on the Belvedere bastion included anadditional entrance to the Fortress stopping and consolidating the materials and masses shattered over the course of two centuries, linking internal paths with walkways, stairs and aerial bridges and reconstituting the walkway (Fig. 27). The monument has thereforebecome accessible to thousands of people who are attracted to the place and attend various cultural events.

Figure 27. A new bridge over the "Belvedere Bastion" destructed in 1800 by the Napoleon troops

Open areas inside the Fortress connect places and time. The original floor level was raised in the past to reach four meters in height, altering the initial layoutof the open spaces. This was due to a number of factors: the considerable alterations suffered by the Fortress with the destruction of all the buildings by the Napoleonic troops in October 1800; the subsequent transformation of the interior into a shapeless and meaningless area; changes to the original internal level by obstructing the excavated lands; and the construction of the water tank.

Restoration works and findings link the past to the present. Excavations were then carried out until the original altitude was identified, assuming it to be about four meters lower than the height of the ground at the beginning of the operations, a quota that was to be reached wherever possible, but obviously not around the water tank, which was considered fixedat the center of the Fortress. Many areas and passages recorded in the historical cartography were found and, thanks to further tests and a few fortuitous findings, important artefacts belonging to post-ancient and ancient times that predated the sixteenth-century defense building came to light.

In the area between the Diacciaia and Soccorso bastions the remains of a building from the Augustan age were found, with extensive stretches of mosaic pavement in good condition and elevated parts ofwalls with plaster and colours still preserved – an area currently under study and awaiting furtherexcavation and a potential repurposing. In the space between the Chiesa and Soccorso bastions, anunderground area was unearthed – probably a church built in the late medieval period and used as acrypt in the sixteenth-century church destroyed by the Napoleonic mines. And finally, many findingsbelong to the remains of medieval buildings and fortifications and also to works that were probablycarried out according to the first plan of the Medici Fortress by Antonio da Sangallo the Elder and hisbrother Giuliano, then covered up and modified by the project of Antonio da Sangallo the Younger. As yet unfinished, the open spaces inside the Fortress have been redesigned and create a sequence ofpaths at different levels, connected to a gentle slope accessible at the lower levels, with a high centralarea corresponding to a height of about one meters above the upper surface of the tank floor.Viewpoints overlooking the archaeological sites have been set up and designed in perspective asstarting points to reach the excavations and their final arrangement. The patrol walkway - redefined and completed with metal bridges to compensate for collapsed or unusable parts – once a place for sighting and controlling over the land and the conquered city, is nowproviding new perceptions and views of urban and territorial landscape. At the center of the Fortress,above the tank that is still in use, a space dedicated to contemporary culture provides open-air seating,a stage and a sub-stage equipped with dressing rooms, technical rooms, toilets and warehouses.

Contemporary art bursts into rediscovered places with an unexpected welcome. As already mentioned at the beginning, a long-term strategic choice by the local council included temporarily housing new sculptures in the Fortress, with the aim of creating a cultivated dialogue among: symbolic values; the dense language of present-day art with this place, or rather, places; andthe highest artistic and architectural expressions of the city and land of Arezzo. The centre of this dialogue should house art's timeless time; stories vis-à-vis history; linguistic research as the ultimateexpression of intense poetic values; the reciprocal, ever-new revelations about the history of the defensive building and of the city that, each time, should have been made to visitors by the Fortress and other iconic areas of the city of Arezzo on the one hand and art installations on the other. The rooms in the Spina and the Diacciaia bastions have hosted many works by very famous artists such as Ivan Theimer, Ugo Riva, Gustavo Aceves, Mimmo Palladino (Fig. 28, 29, 30, 31, 32).

Figure 28, 29, 30, 31, 32. Contemporary sculpture exhibitions held in the Arezzo Fortress

The long narrative of the spaces and rooms in the fortress, enhanced by the restoration project, embraces work of art which in turn recount time and history and yet include classical art themes. Such a choice provides a far greater sensory effect and a more intense dialogue than could be offeredby displays of contemporary art heavily contrasting ancient surroundings which tend to produce a preconceived form of otherness.

INVESTIGATIONS AND RESTORATION PROJECT OF THE CITY WALLS OF SUZHOU- CHINA. The activities that led to the understanding of the state of conservation of the walls of Suzhou, in the Panmen area (Fig. 33), were conducted starting from July 2019 with a survey campaign thatinvolved a group of Italian specialists, coming from Florence University and private companies with the collaboration and supportof Chinese technicians and professors.

Figure 33. The Souzhou Panmen area antique walls

The digital survey. The digital survey of the Souzhou walls has been structured in two main parts: 3D laser scanner survey and photogrammetry (Fig. 34, 35, 36). Both the operations took about seven to 10 days to becompleted.

The photogrammetry was operated an all the surfaces of the walls. A large part of the shooting of theinternal parts of the Watergate was done using a boat, which allowed to take a complete and accurate coverage of all the internal walls and vaults. The photogrammetry processing was operated dividingthe pictures into coherent groups, isolating homogeneous part of the walls and treating them one by one to obtein a sub-selection of 20 groups, allowing a complete and progressive monitoring and immediate use of the resulting models (Fig. 38, 39).

Geophysical surveys at the Suzhou Panmen historical area The Team conducted a non-destructive investigation (3D ERTand GPR) of the structures of the Panmen gate andsurrounding ancient city walls, aiming to: investigate the internal core of the ancient masonry (Fig.40), reconstruct the stratigraphy under the foundations of the accessible structures, identify the presence of heterogeneities in theancient wall structures and/or in the soil below theirfoundation, correlate them with the visible settlements, assistthe work of restauration experts with information relative tothe type of construction and extent of foundations.

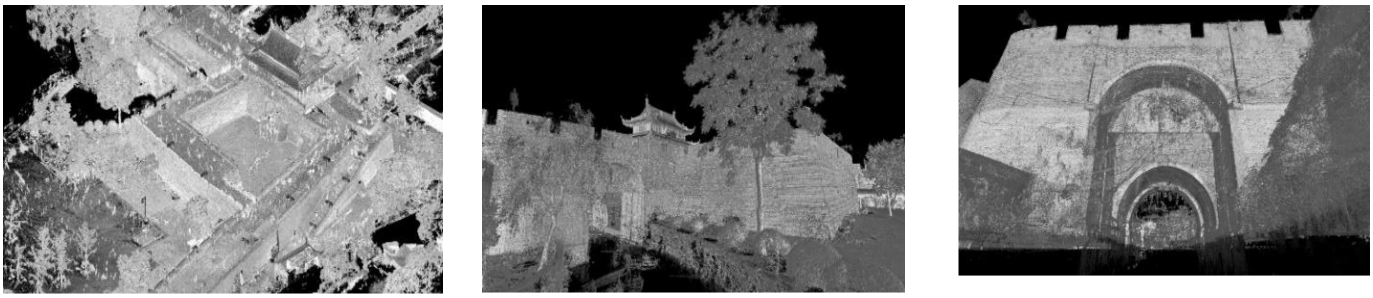


Figure 34, 35, 36. The laser-scanner survey of the Panmen area

The point cloud was the base to define all the following drawings (Fig. 37) and creating the complete reference bases for the photogrammetry processing.

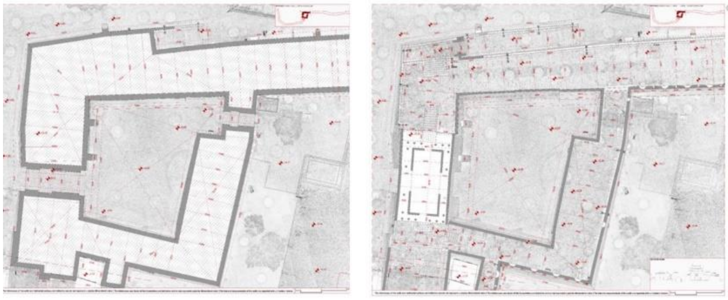


Figure 37. The laser-scanner survey and the plan of the Panmen are

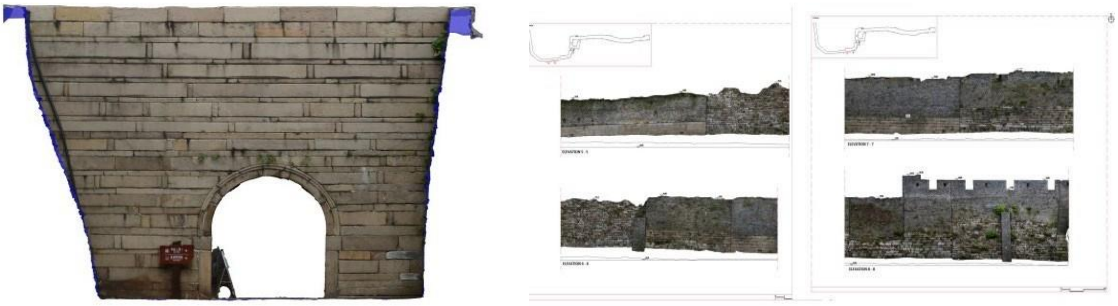


Figure 38, 39. Ortophotos of the walls elevations from the photogrammetry processing

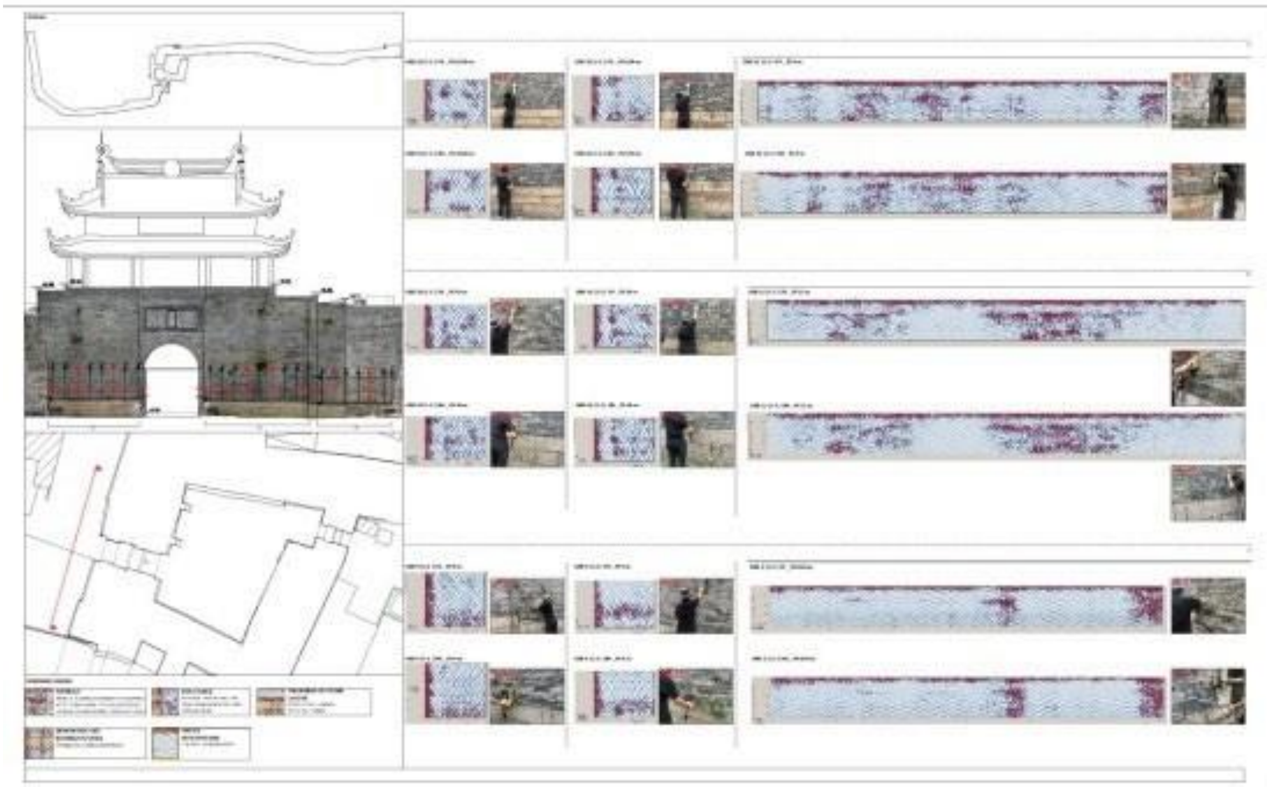


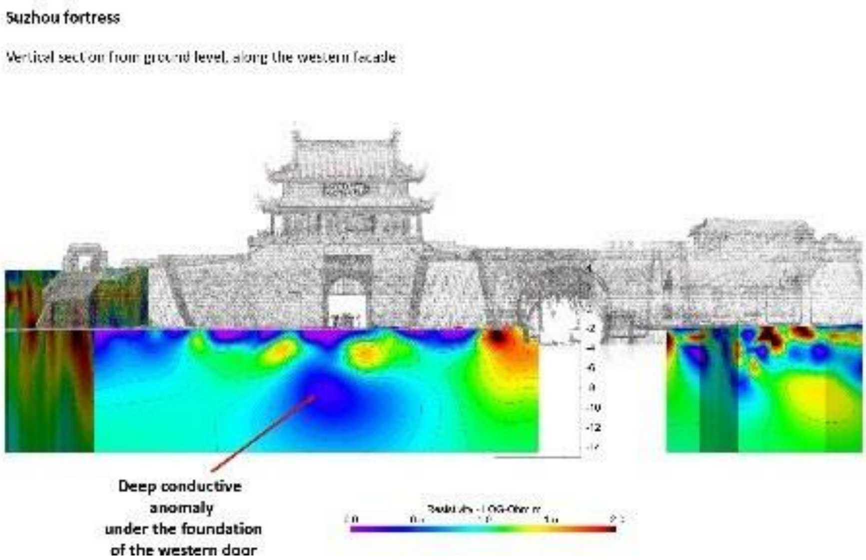
Figure 40. Results of the Georadar investigations

Electrical Resistivity Tomography (ERT) method was used to determine the subsurface distribution in three dimensions of resistivity, a physical parameter of the materials that is related to key physical parameters such as soil/rock type, mineral content, porosity and degree of water saturation. Resistivity measurements are made by injecting current into the ground through two current electrodes stakes (transmitters) and measuring the resulting voltage difference at two potentialelectrodes (receivers).

The 3D ERT maps obtained for the Panmen bastion, though, show that many portions of the walls arecharacterized by very low electrical resistivities, (Fig. 7), due to the high humidity and the presence of clay material with organic matter and peat (Fig. 41, 42). Following these observations, the high-frequency GPR data were then concentrated on the bottom 2meters of wall from the ground, to determine the thickness of the external layer of stones and the density of voids and other anomalies.

Samples collection and analysis. During the activities carried out in Suzhou, samples of brick, stone and mortar were taken. These samples were brought to Italy and were analyzed by the LAM (Stone Materials Analysis Laboratory) of the University of Florence, one of the most important and accredited historic materials analysis laboratories in Italy and Europe. The results of the analyzes are reported both as reports and technicalsheets that are part of the restoration project of the walls of Suzhou. Here are some summary observations. From the sampling carried out, 11 samples were analyzed. Other samples havecharacteristics comparable with those chosen for analysis. These were subjected to mineralogical and petrographic investigations.

The degradation analysis carried out in the Florence office. The degradation analysis of the different portions of the Suzhou walls has been carried out following the UNI EN 1182:2006 (ex Normal1/88) combined with the ICOMOS-ISCS (International Council on Monuments and Sites) illustrated glossary on stone deterioration patterns, an important international tool for scientific decay phenomena description. The different degradation problems have been analyzed and described with colored and graphic patterns on a large number of boards. Thedifferent forms of degradation, for each stretch of wall, have been reported on two consecutives.



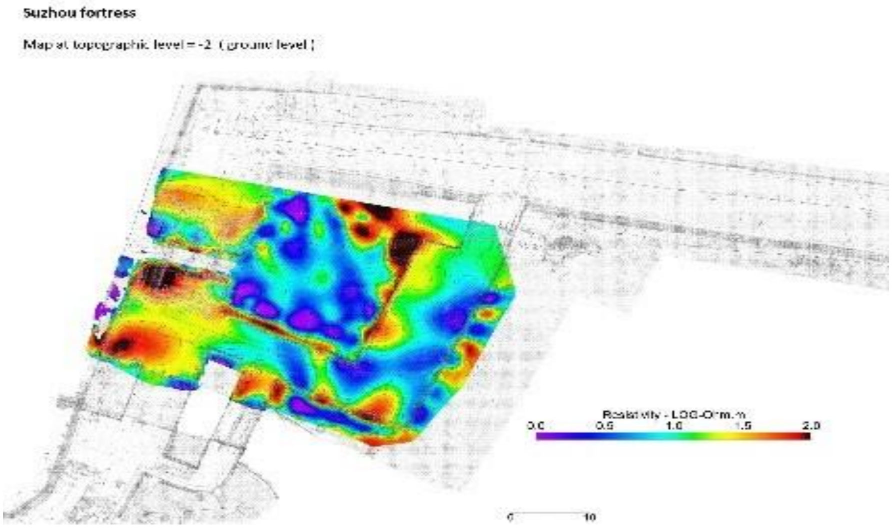


Figure 41, 42. Results from the 3D Electrical Resistivity Tomography of the central portion of the walls

Legend of project intervention. On the basis of previous experiences in Italy and internationally, the following various restoration interventions have been identified and reported on the drawings that make up the restoration project (Fig. 43).

- technical-scientific documentation including mapping ofdegradation and operations carried out, including final report;
- careful hand removal of incongruous layered elements with theuse of chisels and small tools;
- removal of technological elements, wiring, panels, any incongruous elements;
- treatment for the growth of superior vegetation ormicroorganisms of biological origin;

Figure 43. One of the decay analysis and restoration project boards om an ortophoto

- Removel of filling of incongruous material with replacement of material similar to the original one;
- removal of the concrete mortar with both manual and compressed air chisels and hammers;

- dry hand cleaning operation for the removal of particles, dust, soil and guano; cleaning of stable stone surfaces by washing with deionized water spray at low pressure; in case of “sculptural” stony elements cleaning with washing with nebulized water at limited pressure. Applications of paper pulp and ammonium bicarbonate compresses;
- disinfestation from colonies of microorganisms by applying a suitable biocide product;
- sew-on masonry by mending punctual lesions or disconnected portions performed with stoneequal to the existing one, tied with suitable mortar, grouted externally with lime mortar;
- realization of perforations for insertion of fiberglass bars for the consolidation of detached parts;
- reestablishment of cohesion with the application of two coats of ethyl silicate, applied by brush;
- removal of heavily degradated elements and tessellation of missing or degraded bricks or stones;
- superficial sealing and grouting of the joints of the brick and stony material with suitable limemortar;
- interventions on the portions of the top cover in stone or brick applying hydraulic mortar, smoothing with a special stick of iron and modeling of the joint to favor the outflow of water;
- careful dismantling of entire portions of masonry in a state of possible collapse. Before disassembly, numbers with removable paint must be affixed to individual elements and photographic documentation and ortophotos must be created. Subsequent disassembly, cleaning of the rear part from incongruous material and realization of a regular vertical plane. Reassemblyof the elements in their original position by making the joints with lime mortar;
- cortical water-repellent protective treatment of stone and bricks surfaces by spray application of water repellent based on oligomeric-organopolysiloxanes or similar chosen after sampling.

Intervention strategies for consolidation and safeguarding of the structural system. The technical investigations and the analyses carried out on the wall face of the Suzhou’s city walls have clearly shown the complexity of the pathologies related to the potential instability of the structures, characterized by a large deformation pattern, with wide range of anomalies referring to constructional elements present on the wall masonry apparatus. From the results of such analyses it is evident that the absence of a constructive uniformity will greatly influence the choices of a safeguard and consolidation intervention strategy, prefiguring the need for an appropriate diversification of the interventions. The analysis has provided in a very clear way how the vulnerability of the wall structures principally depends on the interaction of the structures themselveswith the ground, both that placed in direct contact with foundation system of the masonry walls and that which constitutes the filling present upstream of the perimeter walls, to forming the rampart, withembankment characteristics. The compositional and stratigraphic diversity of the ground, clearly highlighted by tomographic investigations, justifies a corresponding variability of the interaction of the latter with the containment structures, and determines, in the behavior of the walls, a non-uniformresponse in the values of the risk or vulnerability coefficient. However the variability of the situationsconsists of the water content in the soil, but not only; decisive in fact, both for the modalities of incipient instability and for the type of collapse mechanisms, is the position at altitude of the wet ground inside the embankment (Fig.44).

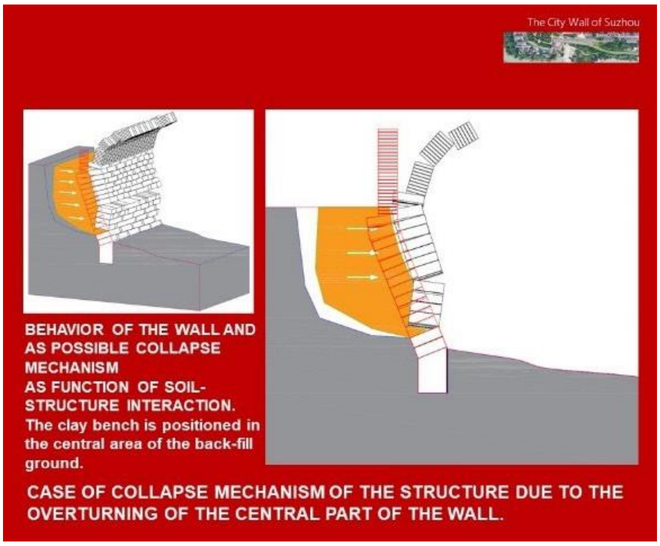


Figure 44. Analysis of collapse mechanism for the consolidation project of the walls

Interventions planned for the east and west side of the walls. A first and essential level of intervention must therefore be to design, at the level of the upper walkwayof the rampart, an adequate drainage system, which collect and channel rainwater, preventing the latter from dispersing into the ground below. These interventions will prevent in the future that the quantity of water coming from the meteoric leachate not only can accumulate in the intermediate levels of the embankment, before intercepting clay layers that prevent it from spreading to the lowerlayers, but also that it continue to filter towards the foundation layers constituting a sliding surface which, as the analyzes have shown, would cause the ruinous collapse of the wall in its entire development for the inevitable triggering of such a kinematical mechanism.

Under-foundation interventions with reinforced concrete continuous side beam. It is possible that the presence of some natural jumps in correspondence of the level of the original foundation oblige to realize a vertical offset of the foundation side-beam, without interrupting the continuity of the structure. In correspondence of each intersection between the side-beam and the brackets, a reinforced concrete drilled piles, with a 30 cm diameter section and an insertion length inthe ground of 8 meters, will be positioned.

Intervention of improvement of the characteristics of interaction and hinging between the wall stonework front facing and the ground behind belonging to the internal embankment, aimed at increasing the static consistency and the stability of the wall structural face.

In general, it will be necessary to provide for the insertion of a diffused semi-deep connection systemof the stonework front facing with the ground behind. This objective can be reached by adopting Bossong-type injected sock anchor devices (identifiable as a sort of artificial “diatons”), equipped with a bolt anchors positioned inside a niche specifically carried out in the masonry front apparatus of the wall, whether in the case that the latter be made of stone or brick elements. The arrangement of these anchors on the wall must follow a quincunx geometry, that is a configuration characterized by staggered parallel rows, with relative axle spacing, inn this case, of about 2 meters. Theintervention described has the function of making the wall stonework front facing and the ground behind interact, improving the anchoring and the general static consistency and the stability of the wall structural face.

Deep anchoring with steel tie rods. The intervention is carried out at the most vertical wall fronts, which, as the analyzes have shown, are more exposed to the risk of overturning. This type of intervention has also very specific characteristics, in the sense that it will be used exclusively at points particularly exposed to this typeof risk. DYWIDAG threadbar anchor is an actively tensioned ground anchor system completely independent of installation conditions on site as well as of existing deviations or alterations. Depending on requirements and steel grades, a variety of corrosion protection methods can be used.

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