The Rivellino degli Invalidi and the fortification system of Turin

14 DEFENSIVE ARCHITECTURE OF THE MEDITERRANEAN

Marco Giorgio BEVILACQUA, Denise ULIVIERI (Eds.)

DEFENSIVE ARCHITECTURE OF THE MEDITERRANEAN

Vol. XIV

PROCEEDINGS of the International Conference on Fortifications of the Mediterranean Coast
FORTMED 2023

DEFENSIVE ARCHITECTURE OF THE MEDITERRANEAN
Vol. XIV

Editors
Marco Giorgio Bevilacqua, Denise Ulivieri
Università di Pisa

PISA UNIVERSITY PRESS
edUPV
Universitat Politècnica de València

International conference on fortifications of the Mediterranean coast FORTMED 2023, 6. <2023 ; Pisa>
Defensive architecture of the Mediterranean, vol. XIII-XV : proceedings of the International conference on fortifications of the Mediterranean coast FORTMED 2023 : Pisa, 23, 24 and 25 March 2023 / editors Marco Giorgio Bevilacqua, Denise Ulivieri. - 3 volumi. - Pisa : Pisa university press, 2023.

Contiene:
[Vol. 1]: Defensive architecture of the Mediterranean, vol. XIII / editors Marco Giorgio Bevilacqua, Denise Ulivieri
[Vol. 2]: Defensive architecture of the Mediterranean, vol. XIV / editors Marco Giorgio Bevilacqua, Denise Ulivieri
[Vol. 3]: Defensive architecture of the Mediterranean, vol. XV / editors Marco Giorgio Bevilacqua, Denise Ulivieri

725.18091638 (23.)
I. Bevilacqua, Marco Giorgio II. Ulivieri, Denise 1. Architettura militare - Fortificazioni - Mar Mediterraneo - Coste - Congressi

CIP a cura del Sistema bibliotecario dell'Università di Pisa

UNIVERSITY PRESS ITALIANE
Membro Coordinamento
University Press Italiane

Series *Defensive Architecture of the Mediterranean*
General editor: Pablo Rodriguez-Navarro

The papers published in this volume have been peer-reviewed by the Scientific Committee of FORTMED2023_Pisa

Published with the contribution of the University of Pisa

Pisa University Press
Polo editoriale - Centro per l'innovazione e la diffusione della cultura
Università di Pisa
Piazza Torricelli 4 · 56126 Pisa
P. IVA 00286820501 · Codice Fiscale 80003670504
Tel. +39 050 2212056 · Fax +39 050 2212945
E-mail press@unipi.it · PEC cidic@pec.unipi.it
www.pisauniversitypress.it
ISBN 978-88-3339-794-8 (three-volume collection)
ISBN 978-88-3339-796-2 (vol. 14 and electronic version)

ISBN: 978-84-1396-125-5 (three-volume collection)
ISBN: 978-84-1396-129-3 (electronic version)
ISBN: 978-84-1396-127-9 (vol. 14)

PROCEEDINGS of the International Conference on Fortifications of the Mediterranean Coast FORTMED 2023
Pisa, 23, 24 and 25 March 2023

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Defensive Architecture of the Mediterranean / Vol. XIV / Bevilacqua, Ulivieri (Eds.)

DOI: 10.12871/9788833397948113

The Rivellino degli Invalidi and the fortification system of Turin

Roberta Spallone[a], Maria Concepcion López González[b], Marco Vitali[c], Franco Cravarezza[d], Fabrizio Zannoni[e], Fabrizio Natta[f]

[a] Politecnico di Torino, Torino, Italy, roberta.spallone@polito.it, [b] Universitat Politècnica de València, València, Spain, mlopezg@ega.upv.es, [c] Politecnico di Torino, Torino, Italy, marco.vitali@polito.it, [d] Museo Pietro Micca, Torino, Italy, franco.cravarezza@hotmail.it, [e] Associazione Museo Pietro Micca, Torino, Italy, fabriziozannoni@yahoo.it, [f] Politecnico di Torino, Torino, Italy, fabrizio.natta@polito.it

Abstract

This contribution, of a multidisciplinary nature, connects the very recent digital survey of the Rivellino degli Invalidi with the decades-long archaeological studies culminating with the 2015-2016 excavations and with the historical cartography that reveals the substantial consistency with the digital survey in terms of position, geometry and shape of the revelin.

Keywords: archaeological excavations, integrated survey, digital modeling, Rivellino degli Invalidi.

1. Introduction

The archaeological excavations of 2015-2016, coinciding with the construction of the 'Galileo Ferraris' underground car park in the area where the Citadel of Turin, built between 1564 and 1566 to a design by Francesco Paciotto, once stood, brought to light some parts of the fortifications that partially survived the 19th-century demolitions of the Citadel, aimed at expanding the city. Excavations revealed an external work of the citadel, the Rivellino degli Invalidi, set up in 1639-40 and completed in the late 1680s, in particular a section of the right face and the gorge front. Together with the revelin, the following have been found: an extensive section of the large communication tunnel between the outer work and the Citadel's square, a 70-metre-long section of the magistral tunnel, located on the extreme left of the Citadel's underground defense front, with two mine branches, and a segment of the wall of the first enlargement of the city, set in 1619 and completed in the 1630s. In 2019 the archaeological area, which had been open to the public since the previous year, was the subject of graphic analysis, digital survey, and interpretative modelling by the authors of this proposal, which constitute its first and only integrated digital documentation. This contribution is based on decades of archaeological studies on Turin's fortifications and intends to intertwine the new geometric, metric and morphological data with them, with the aim of both relating the new acquisitions with the archival design and survey documentation on the Citadel's above-ground and underground works and developing new chronological considerations on the actual operational conformation of the ravelins in the period 1688-1706 (1).

2. The archaeological survey of the Rivellino degli Invalidi

The Rivellino degli Invalidi, also known as 'del Duca' (of the Duke), represents the first fortified surface work of the Citadel of Turin that has been partially recovered and turned into a museum since the dismantling and partial demolition of the fortress conducted during the second half of the 19th century (Spallone & Zannoni, 2020). The archaeological survey, in addition to the remains of the external work, returned a complex of structures, for the most part predicted and correctly positioned on the basis of the cartographic

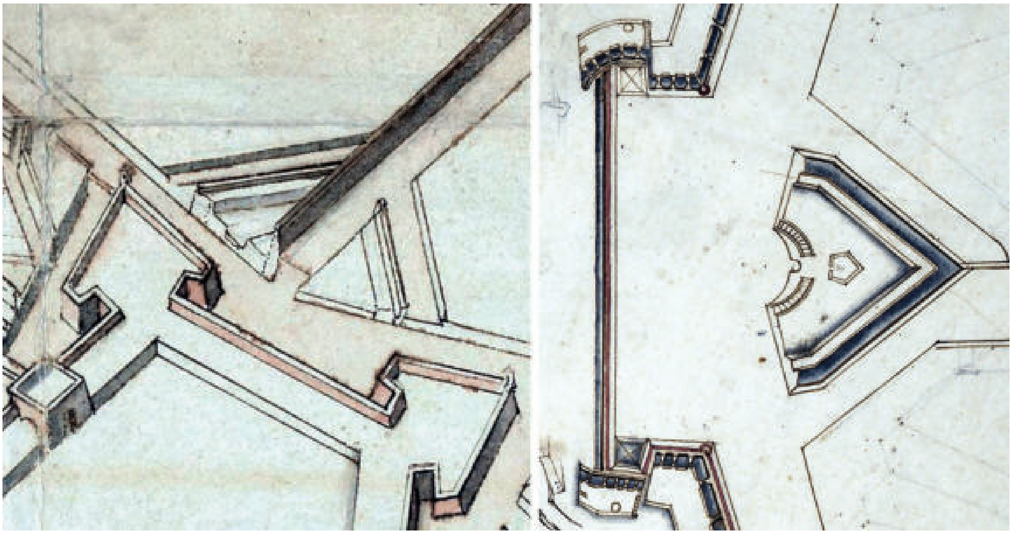

Fig. 1 - The Rivellino degli Invalidi. Left, in 1640 (Paris, Bibliothèque Nationale de France); right, in the late 1780s (Turin, Archivio di Stato)

documentation used during the preliminary study of the excavation operations, distributed, without significant stratigraphic discontinuities, over the entire chronological span of this sector of the citadel's fortifications, from the first phases of the 16th-century construction site to their 19th-century dismantling (Micheletto et al. 2020).

To the north of the eastern side of the Rivellino gorge, a section of the main moat formerly lying between the "il Duca" and "San Lazzaro" bastions has been identified. It was set up in June 1564 and completed up to the planned height, at least for the sections close to the body of the square, by the following November. To this date are the first payments for the masonry work on the curtain walls and ramparts, largely completed by February 1566, when the first artillery was placed on the ramparts' embankments and the construction of the walls connecting the Citadel to the city began, between 1566 and 1567 (Scotti Tosini, 1998).

The second phase identified in the survey area is instead related to the urban fortification. Enclosed in the earthwork of the ravelin is a section of wall with three buttresses corresponding to the western end of the first expansion of the urban walls, designed by Ercole Negro di Sanfront in 1619 and completed, with the masonry covering of bastions and curtain walls, by Carlo di Castellamonte between 1632 and 1637 (Viglino et al. 2008). The fragment brought to light, corresponding to the junction between the moat of the urban fortification and that of the citadel, was largely demolished by the end of the 1680s during the completion of the Rivellino degli Invalidi (Micheletto et al. 2020).

The first nucleus of the future citadel ravelins were built in 1639, on the immediate eve of the "Guerra dei Cognati" (it was about the clash between the brothers-in-law Maurice and Thomas of Savoy, which took place in the late 1630s over control of the duchy), in the form of simple lunettes, outside the 16th-century covered path and provided with a small moat. The drawings of the 1640 siege show how the ravelin in question was created by diagonally cutting the corners formed by the junction of the citadel moat and that of the urban fortification, the communication of which was preserved, thus resulting in the formation of a work divided into two sections. The previously mentioned section of the urban fortification, first preserved as a support for the earthworks of the northern section of the work, was definitively dismantled and largely demolished in the late 1780s, during the final arrangement of the 'Demilune des Invalides', part of the reparation and reinforcement project of the entire citadel by 'S.r Primo Ing.re Ludovico Mauritio Guibert' in the mid-1780s (Micheletto et al. 2020) (Fig. 1).

In relation to this phase, a section of the southern face of the ravelin and the eastern section of the gorge front have been brought to light at a depth of approximately 1.00 metres from the current road surface, i.e., at a height entirely consistent with the demolition methods of the citadel (Spallone & Zannoni, 2020).

The remaining masonry, preserved up to a height of 4.50 metres, was made of cobblestone courses alternating at regular intervals with brick courses. The cladding was made of partly ex-newly manufactured bricks and partly re-used bricks from the dismantling of the western end of the fortification of the first urban extension (Fig. 2).

The ravelin was in fact completed, as were the other four similar external works of the citadel, by 1689, with the completion of the covered path and the vault of the large communication gallery between the external work and the square, the execution of which was entrusted to the engineer 'sig.r Gina'. The tunnel, largely recovered, consists of a first curvilinear section, approximately 16 metres in length, parallel to the profile of the hemicycle containing the ramps for access to the earthwork, which is followed, once the necessary height below the main moat is reached, by a second straight section, preserved for a length of approximately 23 metres. At the same time, the construction of the powder magazine and its communication with the main moat was completed, as well as the access ramps to the gorge, entrusted to the engineer 'Sig. Rubati' (Micheletto et al. 2020) (Fig. 3).

Unlike the other four ravelins of the citadel, that of the Invalidi was not equipped with an inner rampart. In order to protect the powder magazine, the surface of the earthwork was organized on three "terraces" sloping down from the outside towards the front of the gorge, the highest of which constituted the firing platform, while the lower one contained the emerging section of the "Magazzeno da Guerra" (war warehouse), partly buried and built from the bottom of the section of the former urban moat between the two sections of the ravelin of 1639, which was finally filled in on this occasion (Fig. 4).

The last identified -but unfortunately not conserved- building phase corresponds to the construction of the countermine system designed by Antonio Bertola in 1703, built starting in April 1705 and finally perfected in 1709, after the conclusion of the French siege of 1706 (Bevilacqua & Zannoni, 2006). In the northern section of the construction site, a section of approximately 70 metres of the magistral gallery, made entirely of bricks of various dimensions and partly re-used, with a barrel vault and beaten earth floor, was brought to light. Two mine branches started from the magistral gallery, the first with a classical T-shaped plan, 14 metres long, and the second straight, 6 metres long (Fig. 5). With the dismissal of the fortifications, all the works found underwent, to varying degrees, partial demolition work, at the end of which

Fig. 2 - The eastern side of the gorge front of the Rivellino degli Invalidi. In the foreground, a section of the citadel's main moat (photo by GEA S.A.R.T. s.a.s., Micheletto et al, 2020)

Fig. 3 - Communication gallery between the ravelin and the citadel and access ramp to the rampart of the ravelin under excavation (photos by GEA S.A.R.T. s.a.s.)

Fig. 4 - Remains of the powder magazine being excavated (photo by GEA S.A.R.T. s.a.s.)

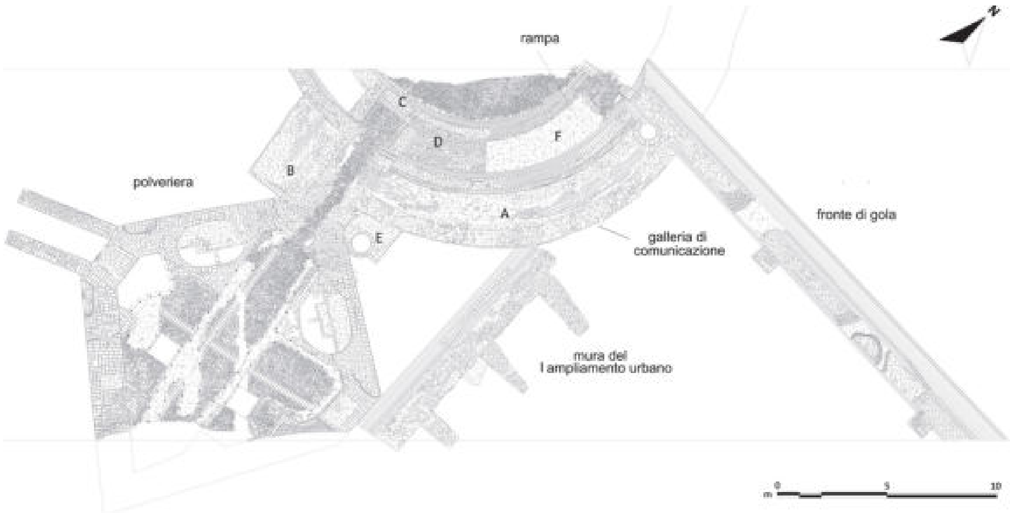

Fig. 5 - Archaeological survey of the Rivellino degli Invalidi (graphic elaboration by Di Silvestre)

the stratigraphic deposits that are the subject of today's recent archaeological research and digital survey described in the following paragraphs were formed, confirming the substantial reliability of the archival cartographic documentation for the precise topographical location of the still-buried works of the Citadel of Turin.

3. Digital survey

This is a complex structure, both in terms of morphology and spatial organisation. The distribution on several levels, the irregular shapes, the variety of construction techniques and the difficult interpretation of the layout of the spaces, make very difficult the comprehension of the revelin's planimetry.

According to Cabrelles and Lerma (2013) there are three alternatives to approach the data collection of complex archaeological sites: 1) photogrammetry complemented with laser scanning; 2) laser scanning complemented with photogrammetry in some areas; 3) integration of laser scanning and digital images. A terrestrial laser scanner (TLS) has been used for the geometric knowledge of the site, due to its ability to capture the elements with excellent dimensional accuracy (Molina et al. 2021) producing point clouds with point grids at minimum distances and with an extremely accurate description of the shape of a surface (Verdiani, 2019) (Fig. 6). Moreover, a sequence of photographs was used to extract the texture of elements that offer little sharpness in the point cloud.

In addition to the challenging features described above, there is also the environmental context, where some spaces are completely unlit. The revelin has an underground corridor with two adjoining chambers which are not lit. Only a ventilation chimney located in the central section of the passageway barely illuminates a small space. It was necessary to place light points inside the three spaces by inserting an electrical cable through the ventilation chimney and placing sufficient spotlights to ensure that the scanning results would be visible and satisfactory.

This difficult scenario was tackled after strategic planning of the stations in order to avoid blind spots and to favour overlapping between scans.

Twenty-seven stations were programmed at short distances (between 4 and 6 m) as points scanned at longer distances have lower resolution than points closer to each other (Koller et al. 2009).

Given the irregularity of the surfaces, the use of reference spheres was considered optimal in order to ensure the proper joining of the scans by means of automatic registration.

Consideration was given to the need to visualize three spheres from two consecutive scans, located at different heights and not aligned to avoid errors.

The Faro scanner, model Focus-130x3D, was used because of its small size and light weight. It has the capacity to record 976,000 points per second and has an integrated 70 Mpx camera. A

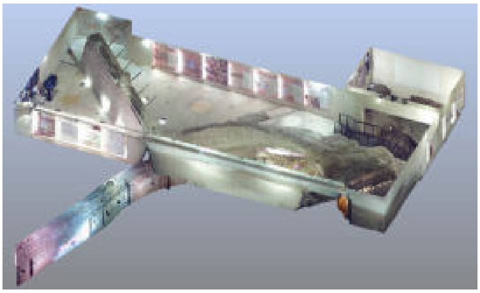

Fig. 6 - General view of the point cloud of the rivellino complete set (processing by López)

Fig. 7 - Orthophotos from point cloud horizontal and vertical sections (processing by López)

total of 234,612,712 points were obtained from the 27 scans. Most of the scans were performed at medium density with a scanning time of between 6 and 8 minutes depending on the amount of information to be processed. The average error was 3.5 mm, which is totally acceptable in an enclosure with these characteristics and dimensions. Also, the minimum overlap between scans was 21.4%, which allowed the method used for the joining of scans to be "cloud-to-cloud".

The software used for the processing, registration and creation of the point cloud was Scene (version 19), associated with the Faro brand.

This program has the possibility of creating sections using cutting planes in any direction by means of the 'clickbox' tool. In this way, vertical sections and floor plans have been created that facilitate the reading of the different spatial levels by determining the irregular shapes of each of the spaces (Fig. 6). The option of creating scaled orthophotos of these sections is very useful for the subsequent digitalization and production of scale plans. The result is similar to that obtained using image rectification processes, and measurements, drawings and other types of representations and operations can be made on this orthoimage (Mañana-Borrazá et al. 2008).

4. Processing and integration of data

The data processed in Faro Scene were exported in .e57 format to be incorporated inside Autodesk Recap Pro, without any loss of information. To handle the subsequent stages of analysis and graphic restitution, operating with software from the same software house -AutoCAD was used for this study- allows for seamless and optimized processing.

In the phase of comprehension of the architectural organism, it was essential to visualize the complex three-dimensional spatiality of the ravelin using the point cloud within Recap Pro. Because of this complexity, numerous portions of the artifact are shadowed or impossible to reach, even as a result of artificial lighting interventions. The overall analysis and observation of the spatial data guided the information selection phase for the graphical restitution, directing the placement of the horizontal and vertical section planes in the thickest areas of the point cloud. The hypogea organism is located ca. 6 m under the current street level (Micheletto et al. 2020: p. 125): in order to assess the elevation deviations within it, we chose to attribute the relative elevation ±0.00 m. at the beginning of the visiting area. The graphic synthesis was done through a selection of the relevant architectural elements to facilitate a comprehensive reading of the geometries of the space. Two levels were chosen to represent the architectural complex in plan view: a ground plan of the uncovered areas of the ravelin in its original configuration, in which the gorge front, ramps, and powder magazine are highlighted; and a plan, at a lower level, including all the interior rooms and the gallery, placed at different elevations to make the spatial and distributive relationships of the complex comprehensible. To supplement the plan drawings, vertical sections were made to highlight the location and shape of the characteristic elements of the work: the gorge

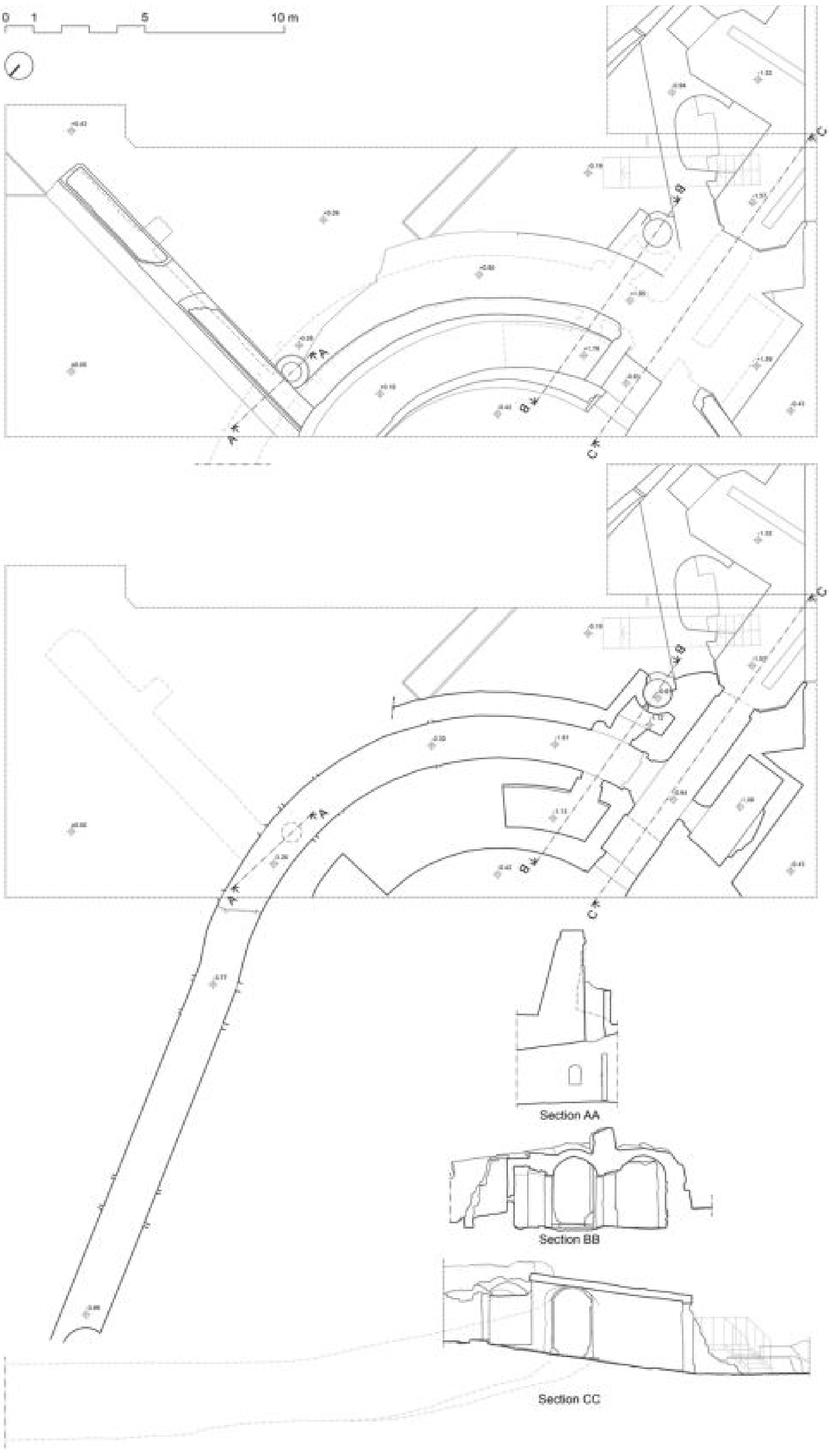

Fig. 8 - Plans and sections of the Rivellino degli Invalidi (drawing by Natta)

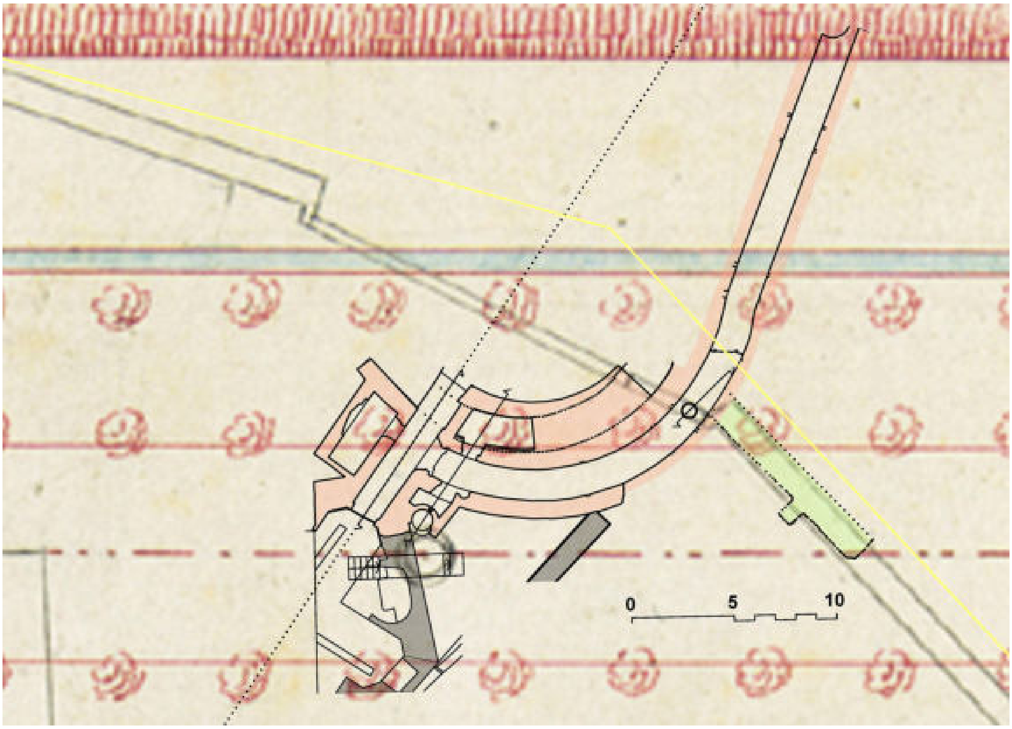

Fig. 9- Detail of Pecco's design drawing (ASCT-ALP_4 doc. 8-2) and superimposition of the survey drawing In red are the masonry intersected by the section plan, in grey those below the section plan, in green those above (graphic elaboration by Natta, editing by Spallone)

front and its relationship to the communication gallery and ventilation shaft, the interior rooms surmounted by the ramp portions, the internal communication links between the Citadel and the powder magazine (Micheletto et al. 2020: p. 133).

5. Graphic restitution

As anticipated in the previous section, the drawings aim to synthetically restitute the complex spatial articulation of the ravelin and describe its consistency with the works carried out for musealization. Specifically, in the two plans (Fig. 8), the thick dotted lines describe the course of the retaining walls of the hypogeous space made of reinforced concrete, while the thin dotted lines describe, both in the plans and in the CC section, the position of accessory elements functional to the musealization of the site, such as the ladder for access to the powder magazine area. The complex distribution of elements at the different levels requires different line thicknesses representation. The plan representing the elements above ground level (the emergent parts in the original

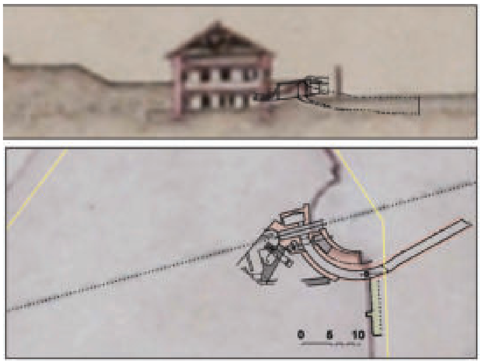

Fig. 10- Details of Chiodo's plan and section AB (Raccolta dei disegni delle fortificazioni, Biblioteca Reale, Disegni, O.XIII) and superimposition of the survey drawing in plan and vertical section along the capital axis (graphic elaboration by Natta, editing by Spallone)

configuration of the artifact) uses projection lines of progressively reduced thicknesses concerning their increasing distance from the projection

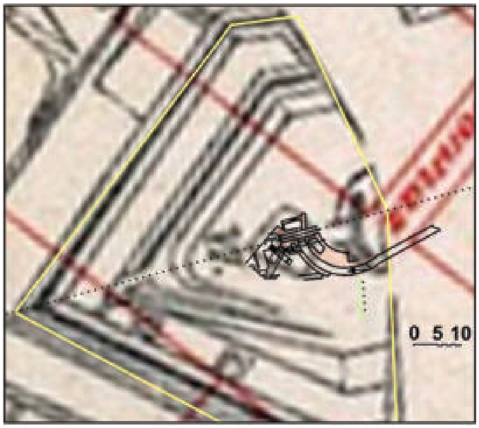

Fig. 11 - Detail of Magni's drawing (Magni, 1911) and superimposition of the survey drawing (graphic elaboration by Natta, editing by Spallone).

plane. Thicker lines describe the more raised elements, such as the top of the gorge front and the curved ramps that run above the tunnel; thinner lines represent the ground attachment of the raised elements; lines of intermediate thickness represent elements located at intermediate heights. Lines in black hatching represent hidden elements above ground level; gray-hatched lines represent (in superposition) the plan at the lower level. The plan of the underground spaces uses a section plan at a height suitable for the representation of the access corridor to the powder magazine and the tunnel connection: this horizontal section plan was appropriately shifted to intercept the steeply sloping development of the tunnel. The levels, distributed on both floor plans, help in the stereometric reading of the complex and are distributed exclusively on the walking areas: the relative level ±0.00 m refers to the access space to the musealized site in front of the gorge front. As for the sections, they describe punctually, in their articulation, the superposition of spaces. In this sense, section A-A, made perpendicular to the course of the gorge front, relates this element to outside and inside the ravelin and intercepts the ventilation shaft of the tunnel located at the lower level (–3.26 m). Section C-C facilitates the comparison with the archival drawings: it passes through the axis of the ravelin capital, intercepting the access corridor to the powder magazine and the entrance to the gallery, depicted in its elevational course through hatching in gray. Section B-B, parallel to section C-C, intercepts the accessory spaces at the gallery entrance and highlights its relationship with the ramps located at the upper level.

6. Graphical comparison of survey data with historical cartography

As seen, the digital survey carried out in July 2019 covered the portion of the underground building accessible to the public through an entrance booth located above ground in Corso Galileo Ferraris. The acquisition made it possible to have metrically stable data on the position, geometry and morphology of the accessible parts in order to be able to make comparisons with historical cartography and the archaeological survey carried out in 2015 during work on the underground car park (Micheletto e al. 2020). In the choice of archive drawings, preference was given to those whose metric and geometric consistency with the built Citadel has already been observed based on previous studies (Spallone & Zannoni, 2020). To these documents were added others that contained the detail of the ravelin. Above all, the drawings representing the above-ground and basement levels through the superimposition of plans or vertical sections were examined.

The drawing of the 'Progetto d'apertura della Stradale in prolungamento della Via della Consolata', drawn on a scale of 1:1000 by Chief Engineer Edoardo Pecco and dated 20 August 1857, shows the section of the new Corso Galileo Ferraris starting from Corso Matteotti (previously Oporto) with the indication of the parts of the Citadel affected by the dismantling and levelling required for the realization of the project. On both sides of the planned road, the territorial sections overturned are shown. In particular, the Bastione del Duca and the Rivellino degli Invalidi are crossed by the road. The superimposition of the survey drawing reveals the correct positioning in the 19th-century plan of the surveyed gorge front (Fig. 9). The "Piano generale delle contromine", by Agostino Chiodo (1846, shows not only the system of underground tunnels, but also vertical sections along the axes of the bastion and ravelin capitals. The superimposition of the current survey on the historical plan shows a remarkable correspondence regarding the masonry of the ravelin front, the curvilinear shape of the ravelin's inner side, and its communication gallery ramps, as well as the access corridor to the powder magazine, on the axis of the ravelin capital.

The section, drawn along the same axis, can be compared with that obtained from the point cloud at the same position, which identifies the downhill corridor and the first portion of the powder magazine (Fig. 10).

The drawing by Pietro Magni, which shows the superimposition of the defence and attack works in the siege of 1706 on the plan of the city in 1910 (Magni, 1911) also assumes the presence of the rests of the ravelin below the roadbed, which is now realised, and shows an adequate superimposition of the current survey with the 20th-century map (Fig. 11).

7. Conclusions

Finally, the present digital survey showed a good geometric and morphological consistency of the recent archaeological survey carried out with traditional techniques.

This result highlights the potential of the integration between the two graphic works: the archaeological survey will be able to acquire metric stability in adapting to the digital one and the latter, in turn completed with a photogrammetric survey, will be able to enrich the stratigraphic and material investigations previously carried out with a chromatic component.

Notes

(1) The research is the result of the collaboration between the authors, pars. 1 and 7 were written by all authors, par. 2 by Cravarezza & Zannoni, par. 3 by López González, par. 4 by Natta, par. 6 by Vitali, par. 6 by Spallone.

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Volume pubblicato nel mese di marzo 2023

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