

Leonardo da Vinci: L'architettura Leonardo da Vinci: L'architecture

a cura di / sous la direction de
Francesco P. Di Teodoro
Emanuela Ferretti
Sabine Frommel
Hermann Schlimme



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Campisano Editore


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Questa pubblicazione è stata sostenuta da:
Cette publication a été soutenue par :



École Pratique
des Hautes Études



histara
Histoire de l'Art, des représentations et de l'administration
dans l'Europe moderne et contemporaine



DEUTSCHES FORUM
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Dipartimento Interateneo di Scienze, Progetto e Politiche del Territorio
Eccellenza MIUR 2018-2022



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FACHGEBIET BAU- UND
STADTBaugeschichte

Coordinamento editoriale / Coordination éditoriale :

Eleonora Caggiati
Marco Di Salvo
Marie Piccoli-Wentzo

In copertina / En couverture :

Leonardo da Vinci, *Schizzi architettonici
e studio per la testa di San Giacomo*,
1495 circa, RL 12552, Castello di Windsor,
The Royal Library

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Progetto grafico
Gianni Trozzi

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Campisano Editore Srl
00155 Roma, viale Battista Bardanzellu, 53
Tel +39 06 4066614
campisanoeditore@tiscali.it
www.campisanoeditore.it
ISBN 979-12-80956-00-2

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Leonardo's experience as a military architect

Stefano Bertocci, Matteo Bigongiari

Introduction

Twentieth-century studies on Leonardo's military architecture have highlighted characteristics of inventiveness and originality that can easily be understood, even by the general public. In particular, this applies to the more elaborate and finished drawings, such as those of the Codex Atlanticus¹, which show the functioning of complex war machinery and military engineering. Italian cultural interest of the last century for the genius of the Renaissance master produced the Milanese exhibition of 1939², organized by a large group of scholars of the time including Ignazio Calvi, who in 1943 published *L'architettura militare di Leonardo da Vinci*³. Carlo Pedretti reinterpreted documents relating to some of Leonardo's works with his publication on the French interventions in Romorantin and with documents relating to the visit to the Verruca fortress in the second Florentine period⁴. For a comprehensive study of Leonardo's architectural drawings of fortifications, we must wait until 1984 with the publication of Pietro Marani's research. He demonstrates how Leonardo's military experiences are linked to learning the skills of the art of war as part of the set of proficiencies that exalt the multifaceted genius of the Renaissance man⁵.

Marani's work is, to date, the most complete text to analyze Leonardo's production on the subject of fortifications, even if, on several occasions, it has been revised and supplemented by other historians such as Carlo Pedretti. Pedretti studied Leonardo's projects for the Isonzo river and added some drawings to the 1984 collection, openly declaring the need for an in-depth analysis of the material sources of the existing architecture, as well as of the historical and archival sources for a comprehensive interpretation of Leonardo's contributions to the field of fortified architecture⁶.

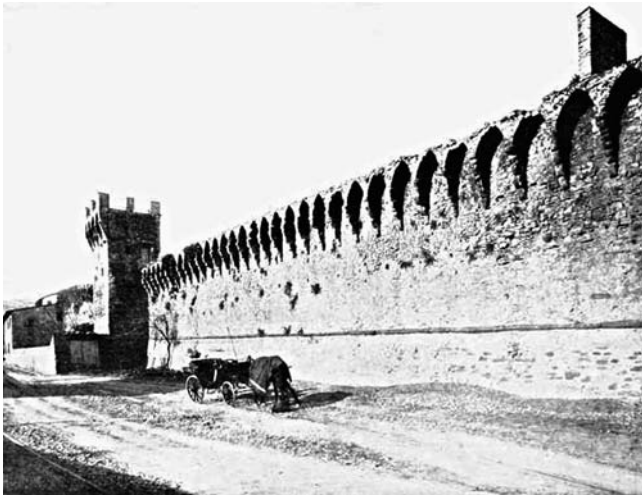
The rediscovery of the Madrid codices⁷ in the 1960s made it possible to focus on the period from 1503 while Leonardo was working for the Republic of Florence. During this period, he took part in the design of the defenses of Piombino, a theme which attracted the attention of Amelio Fara in the late 1990s, and highlighted the

theme of Leonardo's military architecture⁸.

The direct study of surviving architecture with the contemporary practice of digital surveying has made it possible to explore the meaning of the Piombinese architectural drawings and compare them with the city of today, retracing the intentions of Leonardo's projects. These studies began with a research project at the Department of Architecture of Florence coordinated and conducted by the writers which led to the definition of a specific research methodology: this methodology integrates document-based historical research with the study of architectural features and archaeological evidence from masonry, and contributes, through a better understanding of the surviving documents and architectural drawings, to the recognition of Leonardo da Vinci's design innovations⁹. Studies on the ravelin of Locarno¹⁰ have again addressed the themes of Leonardo's military architecture, placing the accent not only on the material evidence of the walls of the ravelin, bearing witness to Leonardo's work in Switzerland, but also and above all on the Italian context during the Italian Wars, during which a revolution of siege and defensive tactics was underway¹¹. The attention to context allowed Leonardo's work to be placed in comparison with that of the architects of his time. The acceleration of the science of fortification of the fifteenth century, when the power of firearms began to be taken into account, contains both innovations and aspects of continuity with tradition that can be found in Leonardo's drawings¹²: in this way the magister of Vinci appears more and more as a figure perfectly inserted in the context of his time, both as a designer and as a careful connoisseur.

In this regard, an undoubted educational debt has already been noted with respect to the work of Francesco di Giorgio Martini, as well as to other contemporaries, such as Giuliano da Sangallo and the Francione workshop; the correspondence of the ideal or real models proposed in Leonardo's notebooks must be verified with respect to the actual construction of the fortified works. It seems evident that this is grafted on to a solid tradition of knowledge of the fourteenth- and fifteenth-century military workshop in relation to the need for reno-

1. Historical photograph of the walls of Lastra a Signa – Florence, 1421-1426



vating fortifications. It is necessary to keep in mind the basic knowledge that underlies all the literary and graphic work of this time: this is particularly evident in Leonardo's work, where the attention to pre-existing structures and the state of the places can be seen in the operational methodology that he constantly implemented, using concrete technical knowledge and starting with a survey of the location to design modernized defensive systems.

References from the Florentine period: examples of military architecture in Tuscany

Leonardo's earliest known drawings show a particular attention to the architectural characteristics of the buildings: in the landscape drawing, (GDSU n. 8P), dated by his hand on August 5, 1473¹³, among the landscape details we note the drawing of a well-fortified town. It seems undeniable that this first approach to the theme of buildings shows remarkable similarities with the military structures characteristic of late medieval Tuscany. In this period the young Leonardo was an apprentice in Florence in the workshop of Verrocchio¹⁴, a *homo intendente* of architecture, from whom it is possible that he learned some rudiments of the profession.

We can get an idea of the military structures that Leo-

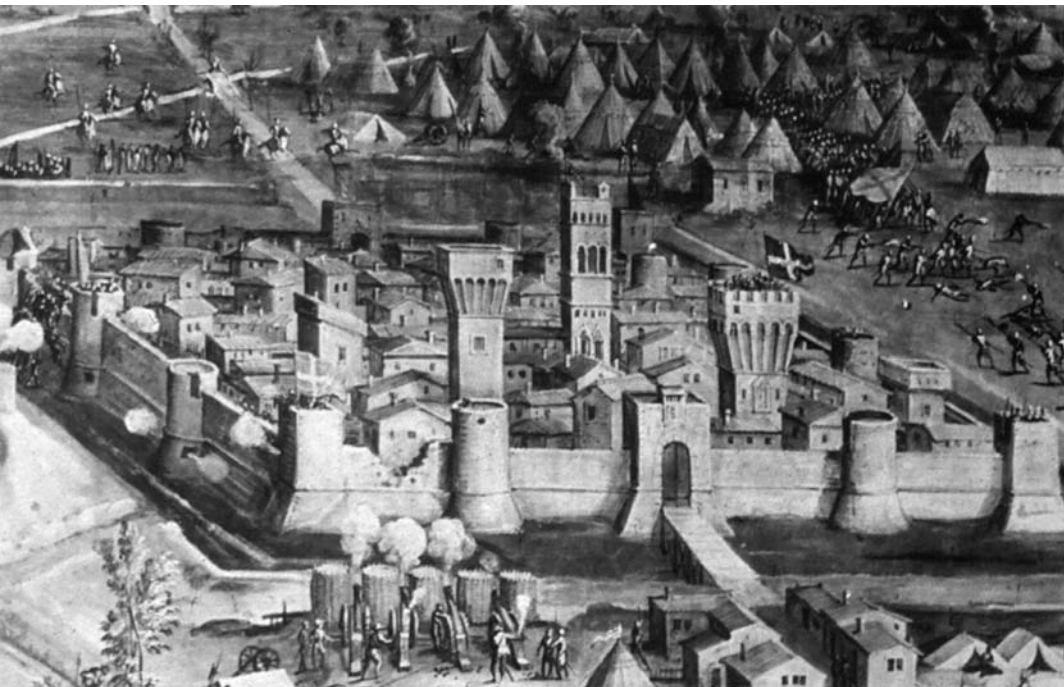
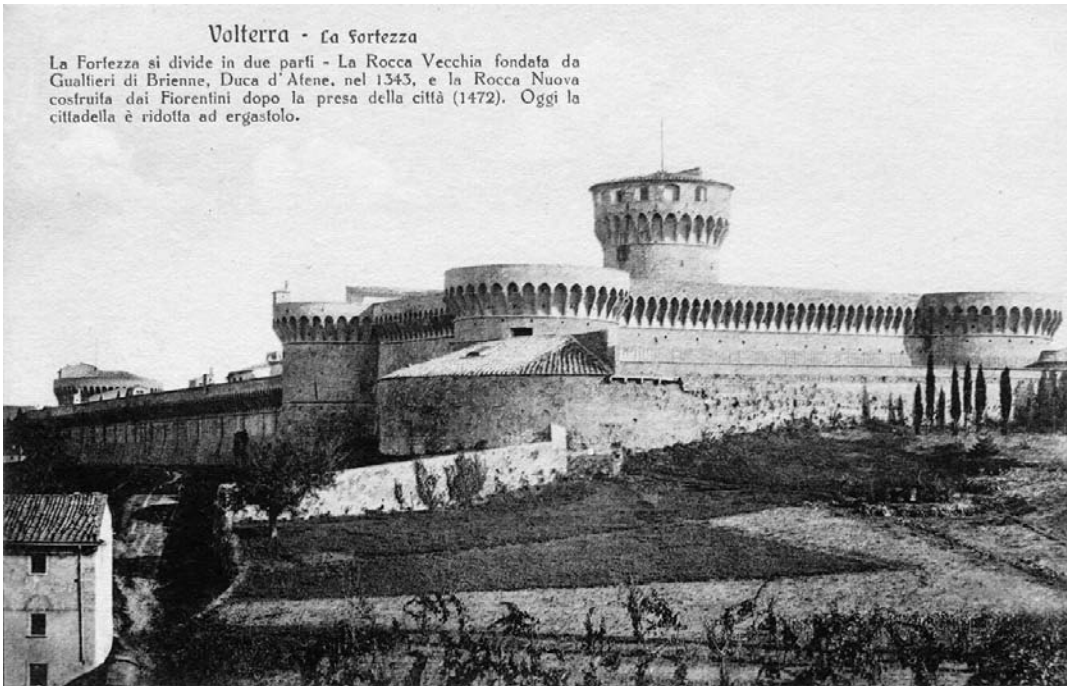
2. The fortress of Sarzanello – Sarzana

3. Aerial photograph of the Verruca fortress – Vicopisano (PI), visited by Leonardo in 1503

nardo may have had before his own eyes and that he would have been able to study in Tuscany. In the Florentine territory there were numerous examples of cities and fortifications, such as the last city wall of Florence, whose design is traditionally attributed to Arnolfo di Cambio, or the whole system of the Florentine New Towns built in the middle and lower Valdarno¹⁵. In the landscape drawing 8P you can see the characteristics of these fortifications that he probably knew well: on the left, high towers protecting the quadrangular walled town. Similar examples could be seen in S. Giovanni Valdarno and Terranuova Bracciolini in the upper Valdarno, or in Castelfranco di Sotto or in Empoli (figs. 4–5) in the lower Valdarno, whose walls were built between 1336 and 1345¹⁶. A comparison between painted landscapes with castles and fortresses, present and visible in Florence, can also be made with Leonardo's landscape, rich in references to the fortified architecture of the Valdarno. For example, consider the *Nativity* of Alessio Baldovinetti in the cloister of vows of the SS. Annunziata, from 1460, or the view of Florence in the fresco of *The Divine Comedy Illuminates Florence*, by Domenico di Michelino, based on a design by Alessio Baldovinetti, built in the right aisle of the cathedral of Santa Maria del Fiore in 1465. Another striking aspect, again in the landscape drawing of 1473, is the definition of the architecture of the fortification on the hill in the foreground on the left. The structure as drawn has been recognized by some as the well-fortified castle on the hill of Monsummano alto¹⁷, while it also recalls more up-to-date defensive types such as the walls of Lastra a Signa (fig. 1), built between 1377 and 1400 to defend the road to Pisa, Malmantile¹⁸, renovated in 1424 or the fortress of Vicopisano rebuilt by Brunelleschi in 1435¹⁹. The structures drawn in the landscape appear very detailed: a wall punctuated with quadrangular-based towers, with a wide escarpment on the outside, as well as the fortress consisting of a building with an escarpment crowned by a crenellated gallery, probably supported by corbels, surmounted by a high tower in harmony with the contemporary Florentine fortresses. If it is true that Leonardo collaborated on Verrocchio's *Baptism of Christ* while employed in that



4. Historical photograph of the fortress of Volterra (PI), modernized after the Florentine conquest of 1472
5. Stradanus, Sixteenth-century wall painting of the siege of Empoli, 1555-1560, wall-painting, Florence, Palazzo Vecchio, detail



workshop, it is possible that he had some notion of the fortifications that are painted in the landscape backgrounds of the master's works such as in the *Madonna di Piazza* in the Cathedral of S. Zeno in Pistoia, where there is a walled city with a gate and bridge over a moat (1475-1483), or *Tobias and the Angel* today in the National Gallery of London (1470-1475), where a turreted gate appears with a bridge crossing a moat. In the *Annunciation* by Leonardo from 1472, which is now in the Uffizi Gallery, a further reference to defensive architecture appears: there is a port city with turreted walls and a tower overlooking the sea, similar to the Torre del Marzocco in Livorno, from the mid-fifteenth century.

From the early Florentine period there is no further documentary evidence of his interest in military architecture, though we will see he declared himself an expert in the subject in the year 1482 when he arrived in Milan.

Leonardo as a military architect in Milan

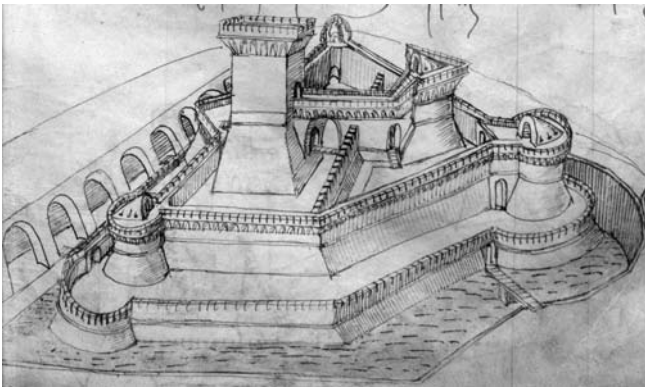
In the well-known letter of introduction to Ludovico il Moro, in which Leonardo lists his abilities, he refers directly to skills as a military architect: in fact in the draft contained in folio 1082r [391r-a] of the Codex Atlanticus he expressly notes contributions to architectural or engineering works²⁰. Despite this evidence, up until 1490 Leonardo was defined only as a Master of art, never as an engineer²¹. The emphasis given to war subjects must be considered financially strategic, as expert military engineers were in high demand due to the political situation of the late 1400s in Italy.

Some evidence relating to a concrete interest in the themes of military architecture can be found in the pages of Manuscript B, dating back to the early Milanese period. The same topics, which were highlighted in the previously mentioned presentation letter, are reflected in the drawings depicting assault systems on walls and castles through the use of wooden stairs or bridges²². Leonardo's earliest studies dealing with the methods of fortification of walls and fortresses can be recognized in the Ashburnham Codex 2037: in these drawings, attempts to improve the defensive potential of medieval fortifica-

tions by building moats and embankments are evident²³. Milan at that time was a magnet for famous artists who gravitated around the Sforza court and worked at the main construction sites. A period of great innovation had begun and Tuscan architects such as Michelozzo or Filarete had already contributed; the latter also had important commissions in the military field for the construction of the defenses of the castle of Porta Giovia. Probably the interest in military architecture places Leonardo in direct relationship with Donato Bramante, whose military duties in supervising the ducal defenses are well known²⁴.

Numerous drawings within Manuscript B depict studies for the fortification of the Milan castle, sometimes representing solutions for the corner tower of the walls, others proposing a triangular-shaped ravelin to protect the Filarete tower²⁵: the ravelin is a defensive apparatus usually placed to protect the access door to the castle or fortification, which will become one of the dominant themes of the defensive architecture studies of Leonardo and other architects of the late fifteenth century. Observing their morphological evolution in the transition from purely medieval to modern defensive functions, they anticipated elements of the pentagonal shapes of the corner bastions in the more mature fortifications of the sixteenth century²⁶. These drawings by Leonardo tend to simplify the geometries of the architecture: some details are not drawn, such as battlements, plumbing and roofs, though they really exist in the surveyed structures, to create a graphic depiction useful for understanding the geometric development and planimetric distribution of the defenses without complicating the general understanding of architecture by inserting superfluous details (see Ms. B, f. 36v).

Following the observation of these drawings, it is legitimate to ask whether such elements are already influenced by the introduction of new forms of fortresses necessary to resist the evolved war tactics. This purpose is evident in the depiction of cannons superimposed on several levels useful for flanking the curtains and defending ditches, and allows us to consider that Leonardo was very familiar with the use of various types of ex-



isting firearms. The presence of the battlements and machicolations should not be considered misleading, even if barely mentioned, because they are part of the attention to the existing architecture as in the case of the castle of Milan, which was already built by Filarete with all those defensive systems, typical of the late medieval period, deriving from a long tradition of knowledge of previous siege tactics.

The problems concerning the fortified architecture that Leonardo da Vinci faced were not unknown to the previous generation of architects; the development of modern fortresses was a process that began in Italy due to continuous battles for dominance over a politically divided territory. It had previously been addressed both by Laurana, for example with the Costanza fortress in Pesaro in 1474, and by Francesco di Giorgio Martini starting from his period in Urbino²⁷. There are also examples in the Florentine territory such as the fortresses of Sarzana and Sarzanello (fig. 2) on which the workshop of Francione had intervened, of which Giuliano da Sangallo was also part²⁸.

The drawings in Manuscript B represent a first approach to the study and design of fortified architecture and for this reason these pages were considered preparatory notes for a collection of descriptive images for an unlikely treatise²⁹. Leonardo studied both contemporary and classical *auctores* as can be seen from the list of books in his possession drawn up in the Madrid Codex II, in which both Alberti and Francesco di Giorgio ap-

pear (fig. 6). Leonardo was certainly able to delve into the study of fortifications through his military art writings, as shown by the annotations found in Manuscript B and the list of readings of the Codex Atlanticus³⁰. The importance attributed to Valturio is evident, in fact Leonardo transcribes many words from his *De re militare*, also applying himself to the study of mathematics and geometry for military topics³¹. These considerations are supported by the studies of projectiles and trajectories, before the flight from Milan in 1499.

Despite the lack of innovations appearing during Leonardo's first period in Milan, he certainly studies and explores the design of fortified architecture, with axonometric sections showing the distribution of rooms within the volumes; as he himself says: «sempre uno edificio vole essere ispiccato d'intorno a volere dimostrare la sua vera forma»³². The similarity, both in form and in the technique of representation from above, of three quarters in pseudo-axonometry, with the drawings illustrating the treatise by Francesco di Giorgio Martini is undeniable; documented contact with the Siennese architect dates back to the time of the design of the lantern of the Milanese Cathedral, in which both Leonardo and Bramante had participated³³. It is probable, although not certain, that Leonardo first became acquainted with the work of Francesco di Giorgio during his stay in Milan, and in particular the first edition of the *Treatise I on civil and military architecture*³⁴.

However, in Leonardo's writings, up to that moment, there are no references to Martini's treatises. In the period from 1490 to 1503, Leonardo appears clearly more concentrated on ballistics and mechanics: the studies on percussion and impacts and their consequences³⁵ considerably influence the development of the shape of curtain walls and fortifications that aim to mitigate the consequences of projectiles by dissipating the impact forces. In 1498, on behalf of Ludovico Sforza, Leonardo goes as far as Genoa to check its defenses, certainly bringing some engineers with him: it is likely that Leonardo went with the Duke, and some annotations inside the Ms. L, which show the names of the places between Genoa and Milan, seem to confirm this hypothesis³⁶.

7. Photograph of the entrance to the fortress of Imola, with the circular ravelin in front of the entrance



The military architecture drawings linked to this period allow for outlining the development of designs clearly influenced by the studies of projectile impact forces³⁷. Various solutions are found for creating articulated walls in order to cushion the impact force of the blows as much as possible: profiles are studied, both in elevation and in plan, that are able to discharge the impact force of the projectiles on two converging inclined walls in order to progressively slow down their motion; these structures appear side by side so as to form a compact front with numerous triangular spurs. However, these ideas do not provide an effective solution in practice: the tip of the spur would have been very fragile, and for this reason it is rightly replaced, in the most advanced solutions, with a rounded profile.

With the French advance, Leonardo's presence in Milan was recorded only until 14 December 1499, while the reconquest of the city took place in early March 1500. Immediately afterwards, Leonardo went first to Mantua then to Venice where, according to some conjectures advanced by Pedretti, he collaborated as a military architect with the Venetian state³⁸.

The assignments for Cesare Borgia: surveys and modernization of fortifications

Leonardo returned to Florence at the end of April 1500 and remained there for two years during which he strengthened his ties with the French monarchy. Then he went to the court of Cesare Borgia where he was em-



ployed at least for a few months as a military engineer³⁹: evidently he had become famous for the expertise he had developed working in Milan and later in Venice⁴⁰. At that time, Cesare Borgia, called Il Valentino, had recruited numerous men to his service to carry out his plan, shared with Pope Alexander VI, of creating a strong state in central Italy⁴¹.

The relationship with Leonardo was formalized with the famous Borgia permit letter in which Leonardo was called an architect and engineer and was granted free passage and help from all the officers of the duchy for the evaluation of military structures held by Cesare Borgia⁴². He probably collaborated on a fortification project for the fortress of Imola (fig. 7): interest in the fortress was strong as shown by the drawings found on the manuscript sheets where he collects the topographical measurements of the city used in making the famous Imola map⁴³. The plan of the fortress is also reported in the Codex Atlanticus (f. 133r [48r–b]) where the relationships between the circular towers and the arrangement of a ravelin are studied.

While traveling across central Italy, Leonardo recorded the morphology of the fortifications in the area between Romagna and the Marches as seen by notes of the surveys carried out in the area: extensive lists of measurements in which the master noted the angles and dis-

tances to reconstruct the fortified perimeters; the perimeters of the city walls of Cesena (fig. 8) and Urbino are represented in the pages of Ms. L (ff. 9r, 9v, 10r, 37v, 38r, 74v, 75r) and in the Codex Atlanticus (f. 779v [286v–b])⁴⁴. Probably Leonardo was in charge of drawing up the plans for the fortifications of the main cities: the master's notes are too brief and concise to allow for the collection of detailed information on the urban fabric, consequently they could not have had a different function⁴⁵.

The same manuscript contains some ballistics studies and related considerations on the destructive effects of impacts on fortifications with some hypotheses for improving the strength of architectural structures: through these studies some forms emerge that seem to enhance the existing designs with sharp spurs. In the projects for Genoa, triangular spurs had been designed to prevent projectiles from hitting straight against the wall⁴⁶, while now the shapes change from polygonal to convex in order to always offer the enemy curved surfaces with deep grooves with inclined sides and a base with a steeper downward slope. Thanks to these characteristics, the architecture is particularly unusual: Leonardo has completely eliminated conventional geometries and flat surfaces. These ideas appear evident in the drawings of folio 39v of Ms. L, which represents a portion of a broken curtain wall with cylindrical spurs and with a parapet that takes a convex curved shape⁴⁷ to deflect a strike. However, Leonardo should not be considered an innovator with regard to military architecture. In fact, these original ideas did not take hold, while in the same period, the first theories and achievements on the bastion defense emerged, carried out by Antonio da Sangallo the Younger, also recruited by Il Valentino.

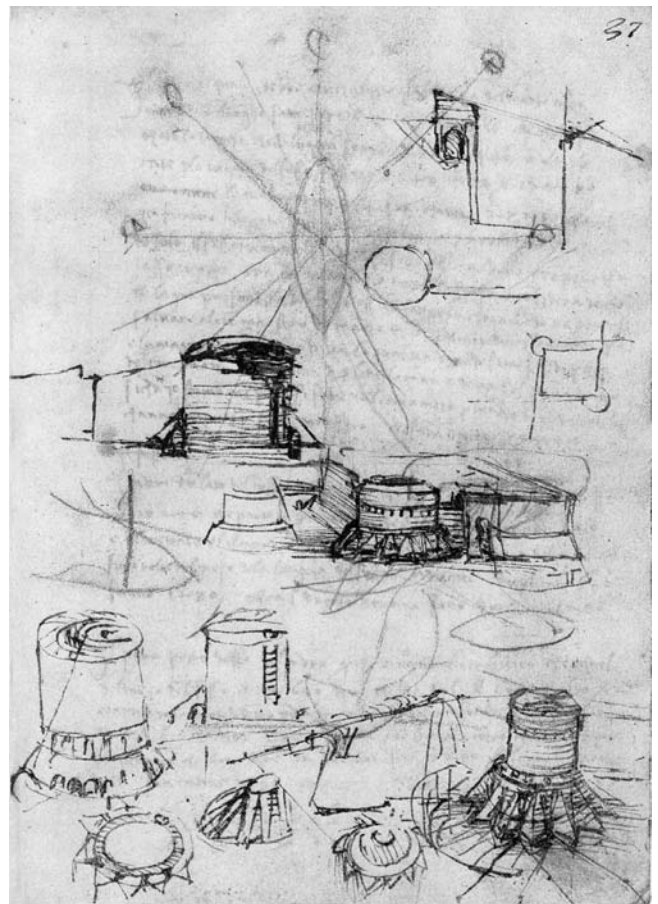
Leonardo has been criticized in the past for not taking into account ways of enabling a counterattack in the design of defensive systems and only showing interest in obtaining structures that are as hard to hit as possible. Observing the drawings, however, one cannot ignore all those studies focused on the insertion of cannons and shooting points from the flanks, considering the necessary systemic defense of the curtain walls and fortifica-

9. Leonardo da Vinci, *Drawing of the modernization project of the citadel of Piombino*, Codex Madrid II, f. 32r, Madrid, Biblioteca Nacional de España

tions, so that no one could approach them unscathed. Similarly, there are numerous drawings of weaponry, which although they are not literally examples of military architecture, are certainly the most direct means of defending these fortresses. The attention to the study of firearms in Leonardo's drawings is evident and has been repeatedly emphasized by many scholars; however, a topic that needs and deserves further study is the representation of numerous defensive systems that allow shooting from high positions, completely irreconcilable with the characteristics of modern architecture, which essentially stipulates moving defenses lower down, hiding them underground, defended by deep ditches as set out and clarified in the words of Francesco di Giorgio⁴⁸. Often misled by the beauty and regular geometry of Leonardo's drawings, analysis of the drawings has highlighted the design and ideal qualities of the defensive schemes, when instead it must be kept in mind that the late fifteenth-century architect and military engineer was constantly pushed to develop improvements to existing architecture, to modernize medieval fortifications, to deal with feasible projects, economically and pragmatically as would have been the case with Leonardo during the missions for Cesare Borgia.

Leonardo as a military architect in Florence from 1503

In the spring of 1503, once the activity for Cesare Borgia was concluded, Leonardo returned to Florence and was sent to the *campo Pisano* to support the war against Pisa. There he presumably advised on the plan to bankrupt Pisa by isolating it from its river access by diverting the Arno to the Serchio river and to Stagno near Livorno. In June 1503 he was also commissioned to inspect the Verruca fortress (fig. 3), of which a view can be observed from the ridge road that comes from the Pieve di San Michele in the Madrid Codex II⁴⁹. Leonardo's interest in the design of modern defensive structures for the fortress of Verruca is shown by the documents found by Pedretti, but to date we have no drawings that document this project beyond the aforementioned view. In 1504 he was sent by Jacopo IV Appiani, lord of Piombino, to fortify his defenses, with the aim of strengthening his friendship with the Florentine Republic: Machiavelli was aware that he had authorized Cesare Borgia to conquer the Principality of Piombino two years earlier. On October 31 he collected the fee for the summer months in Florence and on November 1, All Saints' Day, he was in Piombino: Leonardo organized an inspection with a demonstration of the effectiveness of his projects in relation to the possibility an outside attack, probably aware of the current state of the structures that he had already seen in his previous stay in 1502 when he was in the service of the Borgia⁵⁰. From 1503 Leonardo approached the theories of Francesco di Giorgio Martini more closely as seen by tran-





scribed passages taken from the second version of the *Treaty on civil and military architecture* in the pages of the Madrid Codex II⁵¹ (fig. 9). The shift to military architecture projects that present more traditional and conservative forms may also be due to the concrete problems of construction like the necessary communication and transmission of ideas to workers and the tangible need to adapt to pre-existing buildings and affordable construction materials.

Conclusions

The numerous drawings illustrating the projects for Piombino have been thoroughly analyzed by Fara but a review of the documents in relation to the current state of the places is important for an effective understanding of the innovative scope of Leonardo's designs. For this purpose we are conducting an important research project whose first results are mentioned in the introduction to this work. In our opinion, the project for Piombino rep-

resents a very important moment in the master's career as a military engineer and promises, through further studies and verifications, interesting results on the scientific approach of the design process. Leonardo makes use of both the skills acquired in the study of the texts and creations of the contemporary authors cited in the previous paragraphs, and the specific contributions related to his studies on ballistics, on the resistance to the penetration of projectiles and on the effects of firearms. The commission to work on Piombino appears as an opportunity for concrete experimentation and the synthesis of the knowledge gained over the years (fig. 10). Considering the relative vastness of the drawings and annotations that have been preserved on the Tuscan project, in particular in the Madrid Codex, it is possible to explore the material relating to the modernization of the late medieval defenses and to the figure of the master as a designer.

During his subsequent stays in Milan, Rome and finally in France, the master's prevailing interest in the figura-

tive arts appears. However, Leonardo did not renounce the themes of military architecture; in the Milanese period his presence was found in Locarno for the design of the ravelin of the castle, where the triangular shape for this type of structures is confirmed; in Rome he is interested in the fortress of Civitavecchia, built by his friend Bramante, and finally a lot of attention has been given to the designs for the Romorantin palace, a building that does not appear as real fortified architecture as the French political conditions did not force the sovereign to live in a stronghold or citadel.

There is, therefore, the feeling that Leonardo had already understood how much his own conceptions of military architecture were now overtaken by more effective bastioned structures: the rapid evolution of siege tactics had made it possible to develop the bastion architectures that he had had the opportunity to observe in Lazio working for Pope Julius II and his military architects and probably the experimental architecture proposed by Antonio da Sangallo the younger must have appeared very effective in the eyes of the master of Vinci.

The figure of the Renaissance artist, who embraced all branches of knowledge and the arts through study and direct experience was evidently in decline: beginning at the end of the second decade of the sixteenth century, artists lost their commissions for military architecture because the evolving expertise was less empirical and more linked to developing specific proficiencies. The world of military architecture thus became progressively specialized, with the direct involvement of commanders and professional soldiers on construction sites⁵².

NOTES

¹ The catalog of military architectural drawings can be consulted in MARANI 1984.

² Within the exhibition, much space was dedicated to architecture and the military arts, see IACOBONE 2017. For a critical reading of the exhibitions and legacy that influenced subsequent Leonardo scholars, see FERRETTI 2019.

³ The volume, in line with the Italian spirit of the period, does not miss the opportunity to relate the genius of Leonardo's ideas to the new constructive impulse of twentieth-century architecture; see CALVI 1943.

⁴ To learn more about the French design theme, see PEDRETTI 1972a, while to frame the figure of Leonardo within the Pisan Wars, during the visit to the Verruca fortress, see PEDRETTI 1972b.

⁵ The creation of a unitary corpus of Leonardian representations linked to the subject of military art makes the importance and attention paid by the master to war themes easily understandable, allowing comparison with the volume of the papers produced for the study of other spheres of knowledge. See MARANI 1984.

⁶ See PEDRETTI 1988.

⁷ The first transcription and analysis of the Madrid pages can be explored in RETI 1974; many of the drawings in Codex II are dedicated to military art.

⁸ The early interest in military architecture and the Piombino theme can be explored in FARA 1997 and FARA 1999 respectively.

⁹ Pending the publication of the results of the doctoral research, it is possible to consult the doctoral thesis in BIGONGIARI 2020.

¹⁰ The studies on the Vinciana attribution of the ravelin were published in VIGANÒ 2009.

¹¹ An important conference, (see the proceedings in VIGANÒ 2008), exhibits the advances in fortified architecture of the late-fifteenth century.

¹² The knowledge of the previous generation of artists and technicians cannot be neglected as highlighted in GALLUZZI 1991.

¹³ The study of this drawing was recently highlighted in the exhibition "Leonardo a Vinci. Alle origini del genio", see BARSANTI 2019.

¹⁴ See the catalog of the exhibition that took place in 2019 at Palazzo Strozzi: see DE MARCHI/CAGLIOTI 2019.

¹⁵ The study of Arnolfian projects can be seen in BERTOCCI/BARTOLI 2004.

¹⁶ See FRIEDMAN 1988.

¹⁷ To learn more, see the essay by Guarducci, Rombai contained in BARSANTI 2019.

¹⁸ The walls of Malmantile have been surveyed and recently published in BERTOCCI/PANCANI/COTTINI 2020.

¹⁹ For a study of Brunelleschi's knowledge see BRUSCHI 2006; for fortifications, the monograph of Battisti is still more exhaustive today, see BATTISTI 1989.

²⁰ «2. so in la obsidione de una terra toglier via l'acqua de' fossi, e fare infiniti ponti, gatti e scale e altri istrumenti pertinenti ad ditta spedizione. 3. [...] ho modi di ruinare ogni rocca o altra fortezza, se già non fusse fondata in su el sasso». Codex Atlanticus, f. 1082r [391r-a], Milan, Biblioteca Ambrosiana. For reference see VILLATA 1999.

²¹ For an account of Leonardo's appellations in the documents see MARANI 1984, p. 12 note 1.

²² Referring to the catalog in MARANI 1984, see drawings 8-10, i.e. Ms. B, ff. 23r, 50r, 56r.

²³ Ibidem, see drawing 3 p. 96, or Cod. Ashb. 2037, f. 2r.

²⁴ For further information, see SCHOFIELD 1980, pp. 763-764.

²⁵ For some plans for the ravelin, see drawings 29, 31, 33, or Ms. B, ff. 5r, 24v, 57v in MARANI 1984.

²⁶ See FIORE 2019.

²⁷ The figure of Francesco di Giorgio Martini has been studied in depth in recent times; an important conference (see FIORE 2001), held

on the occasion of the 500th anniversary of his death, catalogues his activities, outlining the significance of such an important figure for the development of architectural and engineering practices of the early Renaissance. In particular, for an analysis of the evolution of military architecture in the Florentine territory see the contribution of Daniela Lamberini.

²⁸ For a detailed analysis of the development of modern architecture in Italy, see FIORE 2019.

²⁹ For example see HEYDENREICH 1954.

³⁰ Similarly, in the preface of the *De divina proportione* Luca Pacioli cites the influential authors in the culture of the period; for a discussion of Leonardeschi studies see VECCE 2017.

³¹ For the importance of Valturio in Leonardo's studies see SOLMI 1908; VECCE 2017.

³² See Ms. B, f. 39v.

³³ To explore the theme see MARANI 1982; MUSSINI 1991.

³⁴ The Salluzian Codex and the Laurentian Codex are identified with in Martini's treatises as examples of this first draft of the text. Compare MUSSINI 1991.

³⁵ Numerous notes contained in manuscripts subsequent to 1490 (Ms. A, C, H, I, M...) contain information and observations about «de moto e percussione», or related to the weight, «de forza peso».

³⁶ See CALVI 1925.

³⁷ Referring to the 1984 Marani Catalog, see drawings 54-72.

³⁸ See PEDRETTI 1988.

³⁹ Two monographs have recently been dedicated to Leonardo at the court of Cesare Borgia: D. Gnola, *Sulle tracce di Leonardo. Il viaggio in Romagna per Cesare Borgia*, Bologna 2019; P. Cortesi, *Il genio e il dragone. Leonardo in Romagna (1502)*, Rome 2019.

⁴⁰ See BELTRAMI 1919, doc. 108; see PEDRETTI 1978.

⁴¹ Machiavelli reports that Valentino «ha cappati i migliori uomini d'Italia». Machiavelli legazione al Valentino, lettera 7.

⁴² Machiavelli notes that the fortresses that fell into the hands of Borgia were left in a state of ruin so as not to facilitate the subsequent defense by the invaders, which is why the experiences and technical knowledge and the services of military engineers were strongly needed. MACHIAVELLI 1961, p. 44.

⁴³ For a study of the restitution of the Imola relief see DOCCI 1987. For a more recent attribution of the measurements see GIBERTI 2016.

⁴⁴ Although clarity has been made on the origin of these measurements, see MARANI 1984, the measurement system adopted by Leonardo deserves further study.

⁴⁵ It is legitimate to point out that the wealth of information present in the Imola map, deriving from the copy of previous annotations, cannot have an exemplary value on Leonardo's method of surveying information relating to the cities.

⁴⁶ Probably taking a cue from the words of Alberti who considered triangular shapes useful *contra missilium iniurias*, see Alberti in *De re aedificatoria*, Book IV, chapter IV, see ALBERTI 1966.

The architectural theory anticipates the forms also used by Michelangelo in organizing the defenses of the walls and gates of the city of Florence in 1529: The same considerations are reported in many examples of the study of ravelins in front of the city gates.

⁴⁸ «[...] e tutte le mura basse sieno non per sé ma e luogo e' fossi [...]», see FRANCESCO DI GIORGIO MARTINI 1979, [IV].

⁴⁹ See PEDRETTI 1972.

⁵⁰ The map of the project carried out in the Borgian period, or f. 115v [41r] of the Codex Atlanticus (see FARA 1999), was deposited in Florence where the survey of the fifteenth-century perimeter of the city's defenses is reported.

⁵¹ Leonardo, who possessed the first version of the treatise, see MUSSINI 1991, noted the arguments of the second version of his interest which had evidently undergone some variations.

⁵² Cfr. BRUNETTI 2006.

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