SCIRES it
SCIentific RESearch and Information Technology
Ricerca Scientifica e Tecnologie dell'Informazione
Vol 13, Issue 2 (2023), 113-124
e-ISSN 2239-4303, DOI 10.2423/i22394303v13n2p113

CASPUR-CIBER Publishing, http://www.sciresit.it

THE HOUSES OF THE SALT WORKERS IN CERVIA

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Abstract

The "houses of the salt workers" in Cervia, Italy, are an 18th-century town planning marvel commissioned by the Apostolic Chamber. These buildings, shaped like a bastioned quadrilateral, house salt workers and their families. Despite some deterioration, they maintain their unique charm. They consist of a basement, two above-ground floors, and a spacious attic, with and without courtyards The conservation project, based on drawings produced following a photogrammetric survey, focuses on preserving the original typology, structure, and materials. This includes reconstructing load-bearing walls, reorganizing façade openings, restoring old brick skirting, and enhancing characteristic arches. This complex holds significant architectural and urbanistic importance as one of Italy's few foundation city examples.

Keywords

Houses of the salt workers, Foundation City, Structure-from-Motion, Restoration, Cervia

1. *Introduction*

Intervention projects on the built heritage can be defined as continuous or discontinuous processes of knowledge and decision-making that concern a building asset throughout its entire life cycle and are organized in different ways depending on the prevalence of objectives and suitable interventions to achieve them. The implementation of planned intervention strategies on the heritage requires a preliminary phase of defining the knowledge and objectives to be achieved. The activity of analysis, monitoring, and diagnosis of the conditions of the building heritage, therefore, plays a significant role within the process.

The results of these investigations allow, first of all, the identification of the type of intervention to be carried out, obviously accompanied by the client's requests. In the built environment, whether historical or not, the cultural values that need to be analyzed and documented cannot be ignored or underestimated. The decision on the real possibilities of intervention on the buildings must be related to the value or set of predominant values recognized or recognizable in them (Valenti et al., 2021). Therefore, it will be necessary to carry out a whole series of analytical and diagnostic activities on the built heritage, necessary to acquire the sufficient level of knowledge to guide the project. The analyses and diagnoses will clearly be tailored to the characteristics and conditions of the case under examination.

Preliminary activities include gathering information about the building, their orderly cataloging, any instrumental diagnostic investigations aimed at understanding, interpreting, and evaluating the state of conservation, operating conditions, and performance related to the building or its parts.

Nowadays, many surveys carried out for the restoration of buildings are done using digital tools such as laser scanners or photographic equipment combined with photomodeling software, whether they are traditional cameras or integrated into a drone (Aterini & Giuricin, 2020). The combination of these different techniques, which can be developed individually or combined into hybrid techniques, allows for the exploration of both the macroscopic and microscopic world. With the point clouds obtained from these instruments, it is possible to obtain geometric and colorimetric information, thus obtaining a model that defines the current state of the structure to be used as a design or maintenance basis for the work. In this way, it is possible to constantly monitor the updating of all information regarding the structure and operate according to the needs.

The photomodelling technique, also chosen for the present case study of the renovation of the salt workers' house, is a useful and rapid solution that allows the reconstruction of real scenes from photographs and some basic measurements for scaling (Yastikli, Cetin & Asamaka, 2022). It provides solid foundations of the representational system, capturing its essence and showing its meanings. Applied to architecture, it is an effective solution for documenting the state of existing buildings, providing specialists with necessary elements for their study or for developing materials for dissemination and enhancement intended for the general public. Photomodelling is an important technique as it allows the creation of three-dimensional models starting from the acquisition of photographic images, obtained with relatively inexpensive equipment, exploiting the principles of photogrammetry (León-Bonillo et al., 2022). In particular, the latest software allows for the generation of three-dimensional images from photographs taken with commercial digital cameras or even mobile phones, achieving results comparable to those obtained using more expensive and sophisticated equipment such as active sensors or laser scanners (Piscitelli, 2022).

Since its invention, photography has been considered a privileged support for interpreting the form, proportions, and other elements that make up the architectural object. Over time, and with the advent of computers, increasingly sophisticated techniques have emerged for the use of photography, defined as "documentary," in order to obtain representations of the object, both two-dimensional and three-dimensional to scale.

The photomodelling technique applied to architecture allows for the acquisition of information with precision, speed, and realism, until now unthinkable with the use of traditional surveying techniques. With the new photomodelling techniques, it is possible to obtain models that adhere to reality, particularly in the representation of surface details and textures. This allows for more comprehensive information about the form, providing the characteristics that make up the built environment and that, through drawing, help us better understand the architecture, at least in its external appearance.

Photomodelling investigates the morphological and geometric conformation only in reference to the exterior of the building, without providing additional information about the stratigraphy of the structures. Refining the process of photomodelling, three phases can be identified through which the model is generated: geometry acquisition through the identification of its spatial coordinates, three-dimensional reconstruction, and the rendering of colors and textures of the surfaces. All these phases are strongly influenced by the photographic capture strategy of the survey campaign and the quality of the photographs. The photographic capture techniques differ depending on the comprehensive acquisition of the morphological characteristics of the buildings or elements composing them.

Very important aspects for choosing the camera for photomodelling include control of the capture, the lens, exposure (which depends on aperture and shutter speed), white balance according to the scene's lighting type, sensor sensitivity, photo sharpness, focus, shutter speed, contrast, building lighting, and image acquisition file format. The most important factor in obtaining a high-quality model through photomodelling is to create a good photographic set from the beginning, considering various factors that can positively or negatively affect the subsequent calculations.

These factors include position, focal axis angle relative to the captured surface, quantity and quality of photographs, lighting conditions, and object surface characteristics. To acquire a series of useful and comprehensive photographs for photomodelling, various photographic survey techniques need to be employed. The main techniques used, either combined or integrated, are parallel-axis capture (simple or multiple), converging-axis capture, and panoramic capture.

These three techniques can be applied both in terrestrial and aerial drone-based surveys (Cianci & Colaceci, 2022). Each photographic set should have a good ratio between the number of photographs and the final result, ensuring the subdivision of the entire object into homogeneous subsets in terms of capture and lighting characteristics: flat facades, facades with protrusions, presence of columns/pillars, ceilings/vaults, floors, etc. The choice of using these techniques depends on various factors such as the scale chosen for model creation, its context, its geometric complexity, and particularly all occlusions, fixed or mobile, encountered from every viewpoint. Since photomodelling is a method for reconstructing the photographed element in three dimensions, the photographic capture must take into account the set of poses in order to measure and enrich the reconstructed geometry (Gutiérrez-Pérez, 2023). This requires making an appropriate choice during camera calibration and orientation. For each point to be surveyed, it is necessary to have at least two photographic captures from different positions, preferably taken with the same camera and focal length. It is also important that the object to be surveyed is fully present in each photo and framed to occupy the maximum portion of the frame; this way, there will be greater precision in data processing. This constraint requires prioritizing obliquely oriented viewpoints with respect to the dominant planes of the building. This also allows for recovering information by identifying homologous points at different depth levels. The ideal case is to acquire images by rotating around the vertical axis passing through the object's centroid. However, it is not always possible to capture photos of a building in this manner due to various occlusions and obstacles, such as the presence of fixed or mobile obstructions and the difficulty of stepping back to maintain the capture distance and frame the entire structure. Additionally, overhead captures would be necessary to fully describe the building's roof, which is almost impossible without the assistance of a camera-equipped drone (Fabris, Fontana Granotto & Monego, 2023). The morphological complexity of the object further complicates the capture phase, as it requires capturing all points of the object by articulating the capture on multiple planes, including some dominant ones. Defining these planes helps determine the number of photographs to be taken, as well as their orientation and position. Each dominant plane should have at least one pair of oblique photographs in relation to it. Additionally, to capture the texture of a surface, it is advisable for the photographic collimation axis to be as perpendicular as possible to the surface being mapped. It should be noted that different techniques can be used, combined, and/or integrated depending on the type of object to be reconstructed and the representation goals to be achieved. Currently available software for photomodelling includes ARC3D, iWitnessPRO, LiMapper, MicMac, MeshLab, Meshroom, Multi-View Environment, Regard3D, Zephyr, and Agisoft Metashape. Agisoft Metashape operates through the automatic recognition of characteristic homologous points in the various photographs, recognized through computer vision algorithms.

Using inverse perspective construction algorithms and photo alignment, it aligns the photographs with each other, initially producing a sparse point cloud. Once the entire set is aligned and the error is distributed, it generates a denser point cloud through classical stereophotogrammetry formulas. By interpolating the points of the dense cloud, it creates a three-dimensional surface (mesh building) onto which it projects the photographs, blending them together to generate the complete texture (texture building).

2. *The "houses of the salt workers"*

The history of the city of Cervia has been intimately linked to its Salt Pans since its birth.

Other relevant economic activities were developed in the sectors of agriculture, fishing and tourism (Benazzi, 2020). The original name of Cervia was Ficocle, also known as "Old Cervia" (figure 1). Ficocle, an Etruscan origin city, was built in the area of the Saline, upstream from "New Cervia" (Foschi, 1997; Guarnieri, 2019). Only archaeological traces remain of Ficocle, since most of the materials used to build New Cervia were dismantled from Ficocle and reused (Forlivesi, 1978). The official building of New Cervia took place after Pope Innocenzo XII signed the chirograph of November 9, 1697, and on January 24, 1698, the first stone was laid in the northern corner of the city (Laghi, 1984; Vianelli, 1988). The construction of the city, because of the formulation given by Count Michelangelo Maffei, began from the side facing the canal, composed of a set of ten contiguous houses, at the center of which is placed the entrance door to the city, called Porta Ravenna, at the ends of which the bastions north and west are located (Lauretano, 2014). A gigantic and industrious building site opened up, to which workers from near and far flocked, in order to create a new city (Quartier, 1987). Finished the construction of the first side, they realized that the primitive project needed changes. It was decided then, in the other three sides, to insert between the houses a courtyard, half dedicated to services that needed coverage and half dedicated to the well, outdoors. The addition of courtyards transformed the square shape in a rectangle of dimensions 270 m x 170 m. In the rectangular enclosure were built thirty-four houses of eight rooms, two houses of seven rooms, nine houses of four rooms, four bastions of thirteen rooms each, for a total of three hundred and seventy-four rooms with cellars and ceilings and twenty-six courtyards with their services (figure 2).

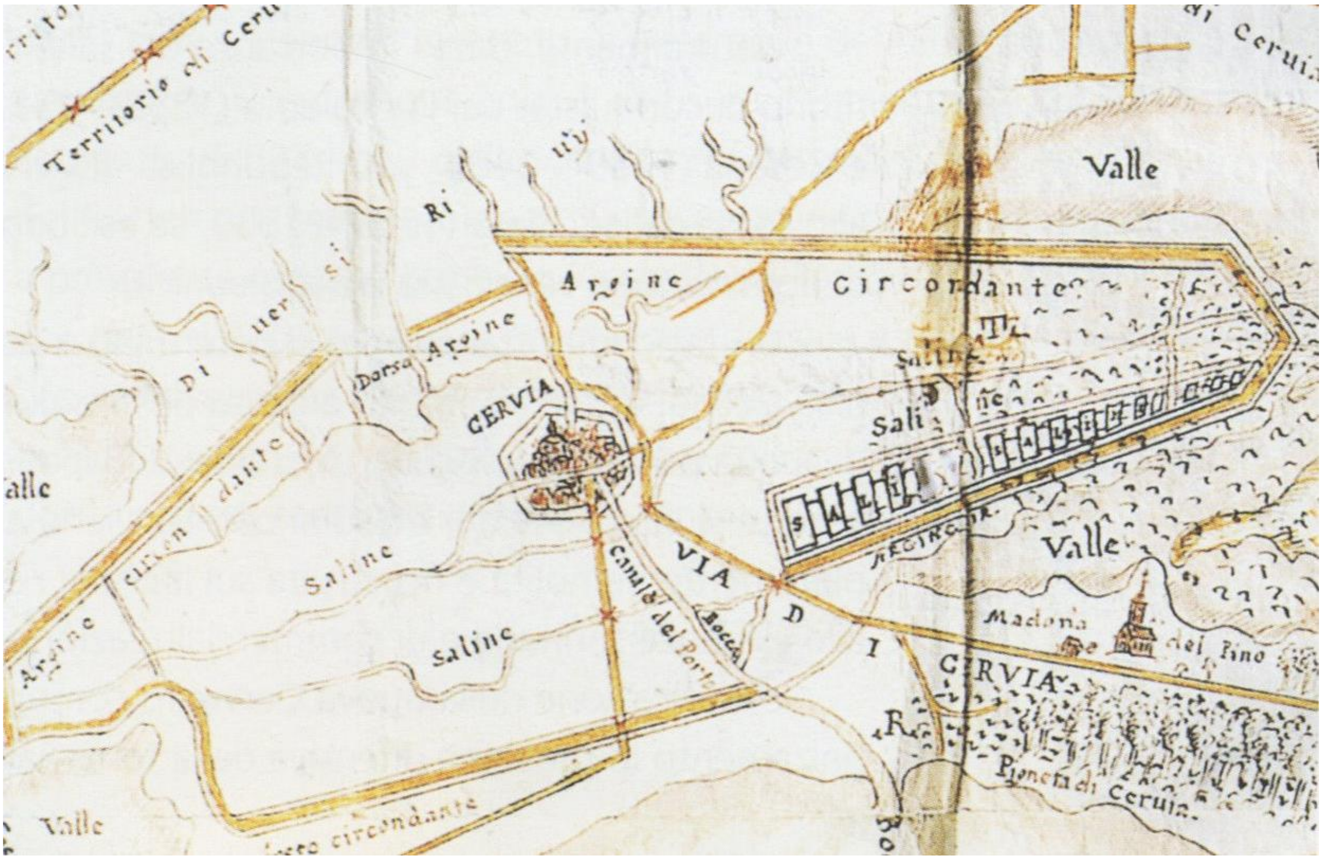

Fig. 1: Plan of Old Cervia and the salt pans, 1606 (State Archives of Ravenna).

The urban layout and the building typologies, which are the result of the various revisions of the original project and of the economic-financial difficulties, express a conception of the new city that was strictly rational, as well as statically anchored to the rigid social hierarchy (Torre, 1960). The project foresaw a closed series of terraced houses, rigorously equal to ech others, arranged along a square profile, which delimited a wide internal space, in which the square, the Church with the adjoining bishop's refectory, the priory palace, as well as four regular blocks arranged in such a way as to identify, in a perpendicular sense to the canal, the main body. At the four corners of the quadrilateral were inserted, to ways bastions stretched wedge outward, larger buildings, containing the essential services for the community, the slaughterhouse, the lathe, the gendarmerie, and the hospital.

Particularly correct is the typological setting of terraced houses, on two floors, with access and central stairwell always facing the outside of the quadrilateral, and with four large rooms per floor.

The basic module provides two apartments per floor, one situated to the right and one to the left of the access, each with one room towards the inside and one towards the outside of the quadrilateral.

The insertion, in recent times, of secondary ramps that are detached from the intermediate landings allows to make also the rear rooms independent through direct connections with the access, creating in this way the possibility to form lodgings with one, two, three, four rooms; a distributive system, therefore, very flexible and functional.

In the four internal blocks are located larger types, intended for the richer classes and the clergy, although ordered according to fixed patterns and easily repeatable. Always built with a double volume, with a wall in the middle, these rooms are equipped with a large anteroom on the ground floor, which gives access to the stairwell, this time all moved adjacent to the rear facade of the building. Despite the subsequent modifications, and even though the building work in the internal blocks also depended to some extent on the initiative of private individuals, the architectural features of the typology have always remained the same: a strictly square plan, a constant height of the façades, a linear sequence of windows, and cornices of homogeneous dimensions, shapes, and colors.

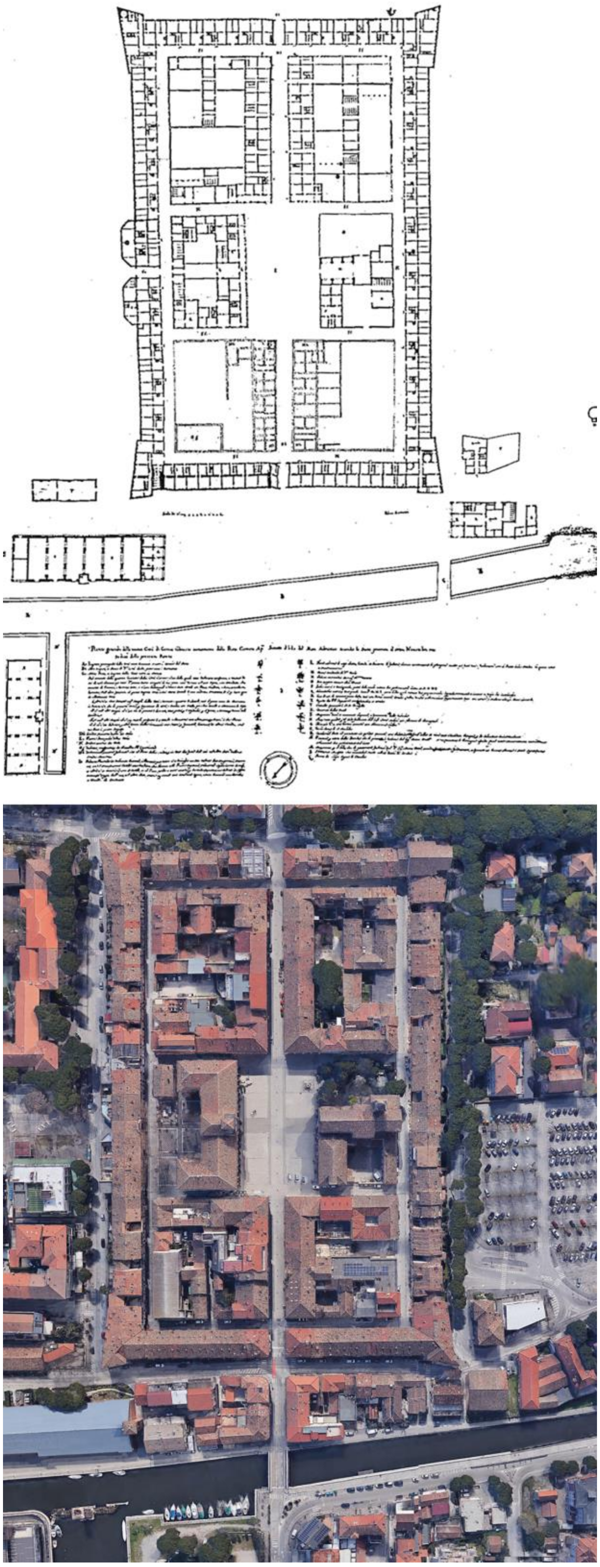

Fig. 2: Plan of Cervia in 1711 (above) and current aerial photo (below).

During the construction of the New Cervia, the original layout was modified: on the east, west and south sides, a small rectangular courtyard was introduced for each type of terraced house to guarantee better ventilation (Gardini, 1998).

Intended as a collective space at the service of the unit, the courtyard was passable, according to a model that remains only in a unit near the bastion of the theater (Gasperoni & Maroni, 1998). Later on, in the courtyard, the hygienic services were realized and again, in a second time, the external body was built, usually reserved to the "camerini": small houses for seasonal workers or for the widows of the salt workers. The doors, one to the north and one to the south, completed the quadrilateral, thus closing the belt of houses which, besides forming the fundamental part of the residential fabric, must have acted as a walled enclosure, giving Cervia the appearance of a singular fortified town (figure 3) (Fabbri, 1975).

The houses of the saltworkers are one of the most interesting examples of minor urban planning from the 18th century. This sequence of two-story houses, all with similar features, built by the Apostolic Chamber in the shape of a bastioned quadrilateral with three symmetrical gates, makes Cervia a truly unique city. Despite the neglect and advanced state of decay in some parts, the houses of the saltworkers still maintain the charm of their peculiarities. The subsequent construction, during the Napoleonic era, of the two appendices of Borgo Saffi, outside the quadrilateral, further complexified this peculiar micro-urbanistic system. The houses located along the perimeter of the quadrilateral, built between 1698 and 1708, and those included in Borgo Saffi, built between 1790 and 1813 as an extension of the city, were born to accommodate the families of salt workers (figure 4).

The salt workers contributed to the construction of the city and thus acquired the right, transmissible from father to son, to enjoy free accommodation. This right was recognized until 1953, when the direction of the State Monopoly eliminated all privileges. Along the quadrilateral there were forty-eight houses; each house consisted of eight rooms, divided almost always by four families. However, at the end of the construction of the houses of the salt workers along the quadrilateral, not all families had a house. In 1790 the construction of the "borgo dei salinari", or Borgo Saffi, began.

The entire complex consisted of eight houses, four on each side of the road, for a total of ninety-six rooms, plus services and courtyards, divided into forty-eight accommodations.

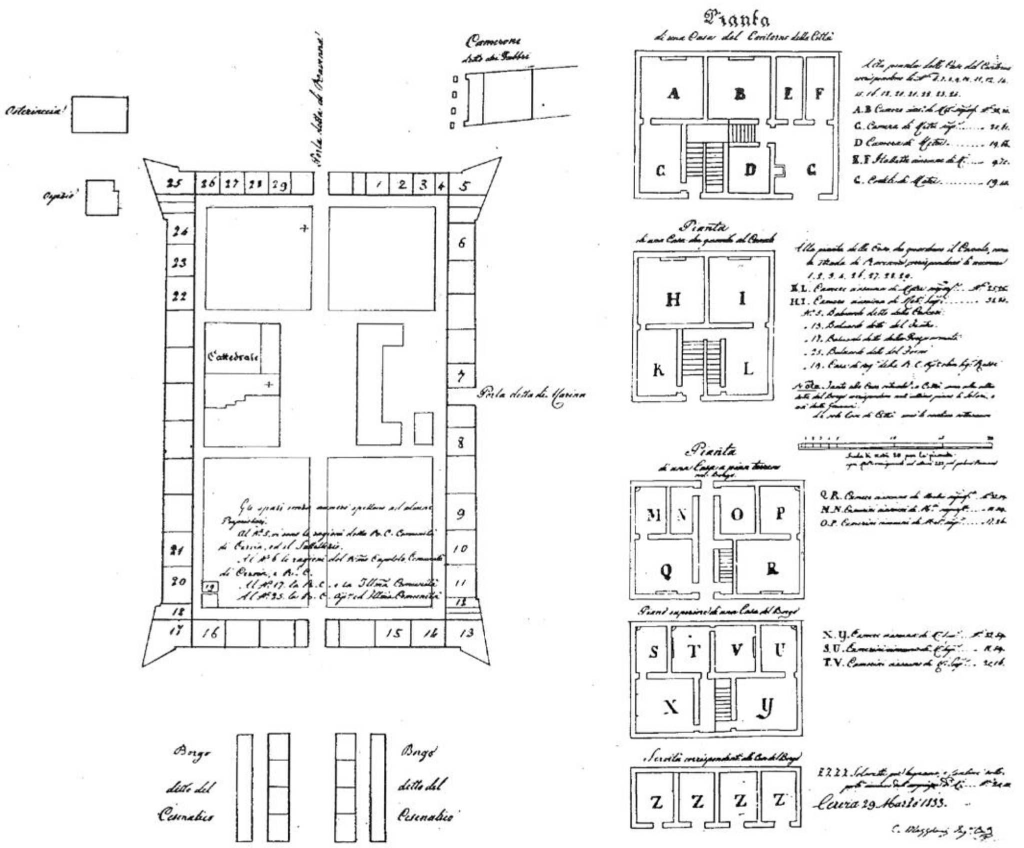

Fig. 3: Left: plan of Cervia in 1833 with the salt workers' houses by engineer Carlo Mazzolani; right: plans of the salt workers' houses in 1388 by engineer Carlo Mazzolani (State Archives of Rome).

The houses of the salt workers were developed on a basement floor, two floors above ground and a large attic, with two rigid types of which the prevalent one with a courtyard and the other one without this.

3. Methodology

In the realm of architectural preservation and analysis, the art of surveying stands as an indispensable tool for unraveling the mysteries concealed within historic structures (Biljecki, Stoter, Ledoux, Zlatanova, & Çöltekin, 2015). Such surveys are no ordinary affairs; they are meticulously orchestrated endeavors that employ a diverse array of techniques and tools to uncover the secrets held by these architectural wonders. In this paragraph, we delve into the multifaceted world of architectural surveys, exploring the amalgamation of tradition and technology in extracting the essence of these architectural treasures (Rueda, Cruz, & Ramos, 2022). An architectural survey is not a mere cursory glance at a building; it is a comprehensive exploration of various facets (Kamnev & Seredovich, 2017). The objectives extend beyond merely ascertaining geometric attributes. They encompass a holistic approach that scrutinizes the structure from multiple vantage points:

- Geometric analysis: at its core, a survey seeks to unravel the fundamental geometry of a building, encompassing dimensions, proportions, and spatial relationships.
- Morphological analysis: aesthetic considerations are vital, as the survey delves into the visual and aesthetic aspects, dissecting the structure's form and overall appearance.
- Technological analysis: the techniques employed in constructing the edifice are dissected and assessed, unearthing the construction methods that shaped it.
- Structural analysis: the surveyors inspect the structural components that provide stability and support, ensuring that the building remains standing through the ages.
- Materials analysis: identification of the materials used in construction is pivotal, as it offers insights into the craftsmanship of the era.

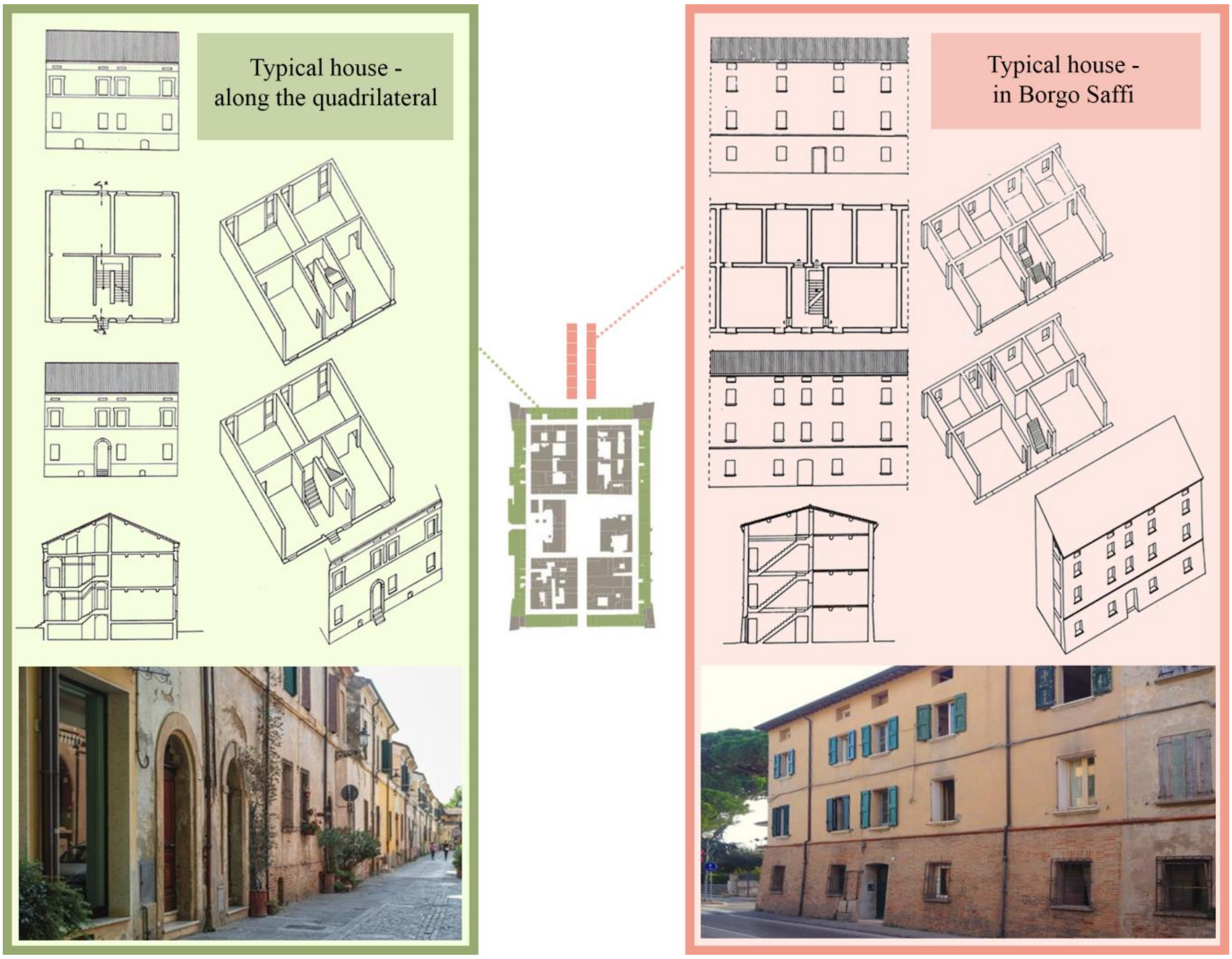

Fig. 4: Typical "houses of the salt workers" schemes and photos, in the quadrilateral and in Borgo Saffi (elaboration by authors).

- Degradation assessment: over time, structures wear and tear. Surveys meticulously catalogue the ravages of time, identifying areas requiring restoration or preservation.
- Urban context: a building is rarely an isolated entity; it exists within an urban tapestry. The survey contextualizes the structure within its urban environment, examining how it weaves into the broader architectural fabric.

4. Results in the case study

The intervention object of study has been directed to the recovery, to the housing purposes, of an integral portion of the "houses of the salt workers" disposed in the greater side to south-west of the quadrilateral, near the theater of the town. Such module is the only one remained, in which the body that looks on the courtyard is developed only on the ground floor, maintaining that perception of void passing between two modules, wanted in origin to obtain a greater salubriousness of the houses.

The intervention, oriented to the maintenance of all the original typological, structural, and material characteristics, has provided to: rebuild the load-bearing transversal walls, which are characteristic of the cellular structure that constitutes the four large rooms per floor; rearrange the facades openings; rebuild the old brick skirting with exposed bricks; enhance the typical arches of the entrances in which stand out the ashlars of impost and key, the stairwell, the courtyard.

The realized lodgings are nine, of which five are located on the ground floor, four on the first floor and in the attic.

A minimal typology of lodging has been chosen on the ground floor, which is well suited to the original structural mesh and four bigger lodgings have been developed with the living area on the second floor and the sleeping area on the attic floor, reachable by an independent internal staircase and balcony. The partial breakthrough of the third floor, to connect the top level to the attic, has been realized with the integration of new wooden elements. Particular attention has been paid to the restoration of the cellars and wet masonry, which were affected by a significant criticality: the foundation base, consisting of brick walls with several heads, was permanently immersed in groundwater.

The impost plane of the foundations is on average -2,00 m from the surrounding street level, while the water table varies up to -1,50 m from the same level, so much so that, on the bottom of the cellars, there is a filling of material of various kinds, deposited by man over time, that creates a lowering of the useful height of the cellars.

In order to use these cellars and thus enhance their ancient beauty, the project has provided for the creation of a waterproof tank inside the cellars, aimed at containing the thrust of the water and therefore at restoring the original height of the floor, after removing the filling material. The final effect is of rare suggestion: together with the full practicability of the cellars, through an intervention of hydro-sandblasting and plastering of the barrel vaults, the foundation walls of the building have been brought back to light, an architectural heritage for too long kept hidden. However, the problem of rising damp on the ground floor has not been solved with this intervention, which does not alter the continuity of the walls. Too high is the level of salinity present in the original solid bricks of these houses and too much is the quantity of water to be disposed by vaporization, moreover, reintegrated by the continuous capillary rise.

The choice of the restoration of the masonry has fallen, therefore, on the realization of an intervention with a coupled method: it has been operated the method of "cutting the walls" with the insertion of profiled PVC foils completely hidden from view from the courses of the bricks of the external skirting and from the internal skirting, combined with a cycle of anti-salt treatment and subsequent application of macroporous plaster based on lime and lime paint, after chiseling, hydro-washing and a period of drying of the walls.

To proceed with such design decisions, it has proved essential to use models (2D and 3D) constructed through the integration of direct surveying and structure-from-motion (SfM) techniques.

The survey conducted involved a comprehensive approach, encompassing both direct and photogrammetric methods to ensure accurate data collection and representation of the target artifact. The direct survey, performed hands-on by an operator, utilized a variety of precise measuring and alignment tools such as meters, metric rods, plumb lines, spirit levels, laser distance meters, and GPS.

This approach facilitated direct contact with the artifact, allowing for precise measurements to be recorded manually on paper, resulting in preliminary eidotypes. These initial representations served as the foundation for more detailed and accurate redrawn versions.

In conjunction with the direct survey, a terrestrial photogrammetric survey was carried out using a Canon Reflex Eos 600D camera, and an aerial survey was conducted using a DJI Mavic PRO drone equipped with a camera, characterized by Megapixels: 12MP, Video megapixels: 8.8 MP (4K), Sensor size: 1/2.3 Inch (CMOS) effective pixels 12.35 M total pixels 12.71M, Max frame rate at 1080p resolution: 96 fps, Max frame rate at 4K resolution: 30 fps.

The complex is in a relatively easy-to-detect condition. In fact, there are no occlusions or impediments to its visibility. For this reason, the number of photographs taken and subsequently processed within the software corresponds to 256 terrestrial photographs and 302 aerial photographs.

The collected photographs underwent a meticulous processing procedure through the Agisoft Metashape software. Initially, the software aligned the photographs with each other, proceeding by separate chunks for terrestrial photographs and aerial photographs, generating a sparse point cloud to establish a framework of reference points.

Once the alignment and error distribution was obtained on the datasets from terrestrial photographs and aerial photographs, the different chunks were aligned by inserting common targets and a denser point cloud was generated, created using the formulas classics of stereophotogrammetry, improving the level of detail (construction of dense clouds).

To create a three-dimensional surface (mesh), the points within the dense cloud were interpolated. Subsequently, the acquired photographs were projected onto this mesh, blending seamlessly with each other.

This process resulted in the production of a complete texture, enhancing the visual representation of the artifact (texture building) (figure 5).

This comprehensive survey approach, combining direct measurements and photogrammetry, ensured the creation of a highly accurate and detailed representation of the facades. To integrate these two methodologies, ground control points were used, which were measured using direct survey techniques and used as references in the photogrammetry process.

These control points were measured with very high accuracy and strategically positioned on the ground using GPS positioning techniques. During image acquisition, these control points are re-captured, allowing for the georeferencing of the 3D model generated by photogrammetry. The integration of these two methodologies has allowed for the creation of accurate models, which serve as a solid foundation for the design of the intervention.

Fig. 5: Image processing in Agisoft Metashape software of the complex in Borgo Saffi and orthophoto derived from the model (elaboration by authors).

5. Conclusion

The old town center of Cervia is characterized by outstanding architectural features and by a peculiar and interesting historical-urban layout. The historical quadrilateral of Cervia was based on a precise hierarchy between the parts to which corresponded precise social hierarchies which have remained almost unchanged over the years.

Thus, the sequence of terraced houses, the houses of the salt workers, which simulated the rampart walls of the city, were destined to what was then the urban proletariat and still maintain this subordinate condition exclusively for residential use. The four inner quadrangles, on the other hand, represented the traditional places of residence and commerce of the upper classes and power. They presented a privileged side on the courses and a double system inside the perimeter, while their side towards the houses of the salt workers was little built and almost always performed a service function.

The intervention presented in this contribution is part of a broader strategy of urban regeneration and has taken place through a process of renovation and rufurbishment, and in some cases also of reconversion of buildings' use.

This intervention produces not only beneficial effects at the architectural scale, but also at the urban scale: in fact, it also induces an improvement in environmental and urban quality, comfort, and urban resilience to climate change, as well as a recovery of local identity and the revitalization of the city from an economic and social point of view.

This intervention represents a significant and effective example of entrepreneurial and cultural investment, which sees the collaboration between public and private to increase the path of enhancement in the cultural and tourist areas.

Moreover, it is crucial to emphasize the significance of integrating direct survey methods with Structure from Motion (SfM) in various fields. One of the primary reasons for this necessity is that direct survey methods provide accurate and reliable data, ensuring the quality and precision of the obtained results. By integrating direct survey methods, such as ground control points (GCPs) or total stations, with SfM technology, researchers can enhance the overall effectiveness and efficiency of their data collection process. GCPs act as reference points in the data acquisition process, enabling the accurate geolocation and scaling of the 3D models generated through SfM.

This integration bridges the gap between traditional surveying techniques and the modern advancements in SfM, leading to a holistic approach that capitalizes on the strengths of both methodologies.

The integration of direct survey methods with SfM enables better control over the data acquisition process. It allows researchers to validate the accuracy of the generated models by comparing them with the ground truth provided by direct survey measurements. This validation step ensures that the resulting 3D models are reliable and can be confidently used for various applications, such as infrastructure planning, archaeological surveys, or environmental analysis.

Furthermore, the combination of direct survey methods and SfM contributes to cost and time savings. Direct survey methods can be employed strategically to capture key points of interest or ground-truthing data, while SfM allows for the rapid collection of large-scale datasets in a relatively short period. This combination reduces the need for extensive fieldwork and enables researchers to gather comprehensive data more efficiently.

Additionally, the integrated approach offers enhanced flexibility and adaptability in data acquisition. Direct survey methods can be applied in challenging or remote terrains where SfM might face limitations. Conversely, SfM enables the collection of detailed and high-resolution data in areas difficult to access through traditional surveying methods. The synergy between the two methodologies empowers researchers to overcome obstacles and obtain comprehensive and accurate data in a wide range of scenarios.

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