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RESTORATION AND SEISMIC RETROFIT OF "VILLA GUARRACINO". TORRE ANNUNZIATA, NAPLES

The building called "Villa Guarracino" is located in Torre Annunziata, overlooking the bay of Sorrento, in the south of Italy.
The building is part of a large complex, known in the past as "Filangieri's Complex". The construction, also called "The Castle", was built by the French government as a military fortress in 1500s. The destination of the building changed over time, in the last the Filangieri Family used it as residence until 1980, when it was abandoned after the damages caused by the earthquake.
The current owner intends to convert it into a luxury resort with the intention of preserving the traces of its long history, leaving intact the details that the different uses have determined. The architectural design approach takes into account the fundamental rules for the restoration of cultural heritage assets. The scope is to guarantee a current and functional use of the building respecting the classified uses until its state of abandon.
The seismic retrofit design can be classified as seismic improvement intervention in compliance with recommendations and guidelines for historical-artistic buildings, as specified in the Italian code "NTC 2008" and guidelines of Ministry of Cultural Heritage "DPCM 2011".

1. INTRODUCTION

The building called "Villa Guarracino" is located in Torre Annunziata, overlooking the bay of Sorrento, in the south of Italy.
The building is part of a large complex, known in the past as "Filangieri's Complex", taking this name from the Neapolitan noble family who possessed the entire complex in the past century. The construction, also called "The Castle", was built by the French government as a military fortress in 1500s. The destination of the building changed over time, in the

On-site test with Double Flat Jacks

On-site test: Endoscopy

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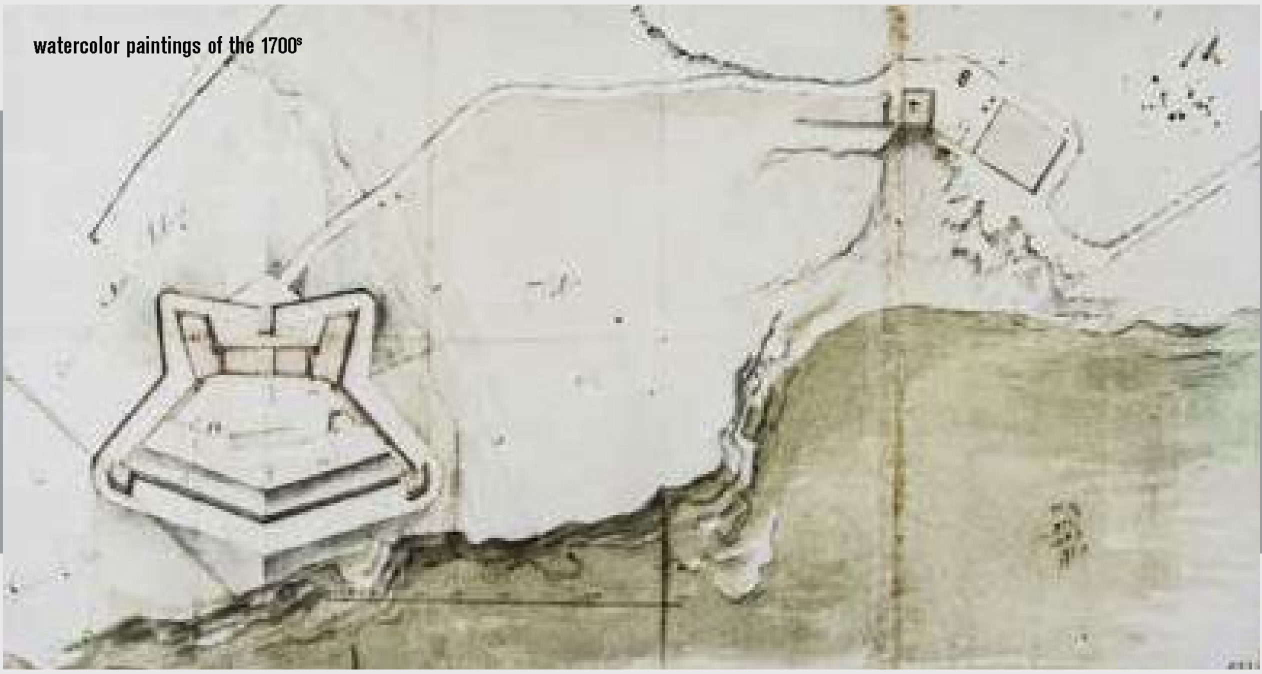
2. HISTORICAL OVERVIEW

2.1. HISTORICAL-CRITICAL ANALYSIS

The building was originally a Bourbon fort in the 16th century for the monitoring and protection of the coast against enemy incursions coming from the sea, it was known as Ancino fortress. The military complex in Cape Ancino gives us the image of a trapezoidal barracks protected by a wide moat and with two sides along the coast, whose sea defence was ensured by two turrets and low-rise bastions with a singular semicircular plan-shape. The profile of the sheltered fortress, just emerging from the promontory, hid an articulated structure with underground rooms used as storage and a large parade ground with the lodging of the commander and the garrison.
The role of the building changed decisively with the birth of the Kingdom of Italy. The fort passed in the property of the State and put up for sale. From that moment and until the first half of the 20th century the fort became the scene of social events for the Filangieri Family.
The new owners did not make efforts to preserve the original structural and functional integrity of the building, but they made several changes aimed to adapt the building to the new destination, except changing the original layout.
In this way, the construction lost one of the elements that constituted the most distinctive aspect of its original function, becoming a typical summer residence for the Family and its guests.


watercolor paintings of the 1700s

2.2. DESCRIPTION OF THE BUILDING

The building shows its character of a military fortress with a U-shaped plan with the long side oriented in an east-west direction, with a direct sea view. The two short blocks of the U-shape are tilted in the opposite direction, one in the north-east and the other north-west. The property consists of the following levels: ground floor with an area of 530 sqm; first level of approximately 320 sqm, which rests on the central long side, while the two lateral blocks are single-story; attic of approximately 125 sqm with a pitched roof.

In front of the building it is placed a pentagonal-shaped courtyard that containing into the two south-east and south-west corners, two emerging towers.

From the entrance on the north side, the structure offers to the visitors the main façade, characterized by a pattern of horizontal plaster bands that cover the entire ground floor, with a central balcony on the first floor surrounded by balustrades. The first floor is characterized by arched windows equipped with patterned decorative friezes. On the top, the façade is crowned with battlements.

Through the aforementioned entrance, which can be accessed by a suggestive 'bridge', the guest arrives in the pentagonal-shaped courtyard.

The interior façade has not particular architectural elements, as it has preserved the austere original military features.

The other façades are similar to those internal and present, as prevalent feature, the only cited lookout towers.

3. RESTORATION AND CONSERVATION DESIGN

The architectural design approach took into account the fundamental rules for the restoration of cultural heritage assets, due to the historical and cultural interest of the building.

watercolor paintings of the 1700s

The scope has been to guarantee a current and functional use of the building respecting the classified uses until its state of abandon: social uses for the ground floor and residential uses for the upper floors. During the stages for the consolidation of foundations of the two side wings of the building, it was found that the original floor was deeper than the external walking level of approximately 3 m and furthermore the filling material was loose type. This revealed the existence of underground rooms used in the past, then filled for some reasons. A similar situation was found in the two lookout towers on the south side.
On this basis, the project provided for the recovery of the relieved underground spaces and their extension outside the perimeter of the building through two new underground volumes, completely hidden from view and separated from the main building by mean of construction joints. In the following it is described in the details the structural project which involved the original main block.

4. SEISMIC RETROFIT DESIGN

4.1 DESCRIPTION OF THE STRUCTURAL SYSTEM
The structural system consists of bearing walls made up with tuff masonries mixed, in certain zones, with soft lava stones. The thickness of the bearing walls is variable both in plan and in elevation of the building.
On the ground floor masonry vaults are visible resting on arched walls. The masonry vaulted structure is the solution used for the intermediate floors and presents different typologies: barrel vaults and rib vaults, widely varying in size. On the ground floor, the system is not well-structured, vaults are interconnected by lunettes or spherical joints; on the upper floors the vaulted surfaces appear simple and more regular.

The roof has a load-bearing structure with wood pillars and beams.
The foundation structures are made with a deepening of the vertical walls of more than 3 m from ground level. The surveys showed the walls go far beyond the first layer of topsoil, resting on the volcanic and lithic soil that is placed in a range between 2 and 5 m depth from the ground level.

4.2 THE KNOWLEDGE PHASE

The project concerned the works to be executed on an existing construction, for this reason it was paid particular attention to the "knowledge" phase of the existing building.
Generally, there are three factors determining the "Knowledge Level" (KL), they are:

- **Geometry**: the geometrical properties of the structural elements and such non-structural elements that may affect structural response;
- **Details**: these include the amount and detailing of connections between structural members, e.g.: connection of floor diaphragm to lateral resisting structure, the bond and mortar jointing of masonry and the nature of any reinforcing elements, etc.
- **Materials**: the mechanical properties of the constituent materials.

In almost all technical specifics (e.g. "Eurocode 8" or Italian code "NTC 2008"), the achieved KL determines the allowable method of analysis and the values to be adopted for the Confidence Factor (CF), the latter the factor that corrects the mechanical properties to be used in the analytical calculations.
In this assignment the achieved KL was equal to KL2 - Normal Knowledge.
The survey on the geometry and details included:

- thickness and typology of bearing walls;
- geometry, composition and layering of foundation, floor and roof elements;
- structural openings details in term of characterization of the structural efficiency of sub-window (sills) or up- doors/windows (spandrels);
- quality of connection between horizontal and vertical elements;
- quality of connection among intersecting bearing walls;
- crack pattern and state of conservation state;
- structural details of other connections between structural elements;
- presence of structural or non structural elements of high vulnerability.

Regarding the knowledge of materials, the experimental tests included:

_ 3 on-site tests with single and double flat jacks;
_ 3 laboratory tests on the mortar;
_ 2 laboratory tests on extracted cores by r.c. elements with execution of compression and carbonation tests;
_ 2 laboratory tests on bars extracted by r.c. elements with execution of the tensile tests;
_ 5 on-site tests by means of Resistograph equipment, for the determination of the quality of wooden elements;
_ several endoscopic surveys through the masonries and the vaulted thickness.

4.3 STRUCTURAL MODELLING AND SAFETY CHECKS

On the basis of all the previous information, the structural model has been defined in order to develop the numerical analysis and the safety checks.
The structural model assessed two different issues: the so called "first-mode" damage mechanisms, which involve out-of-plane failure mechanisms, and the "second-mode" damage mechanisms which are associated to in-plane response of walls.
The assessment of the first mechanism passed through the "kinematic" analysis of collapse mechanisms, generally analysis of simplified partial sub-models (e.g. co-planar two-dimensional models).
The assessment of the "second-mode" damage mechanism passed through the non-linear static analysis for a global three-dimensional model, the so called Pushover Analysis, that is claimed as the more appropriate method for the structural assessment of the masonry buildings.

4.4 DESCRIPTION OF INTERVENTIONS

The interventions have been chosen on the results obtained from the numerical analysis of ante-operam status, fully in compliance with recommendations and guidelines for historical-artistic buildings, as specified in the Italian code NTC 2008 and guidelines of Ministry of Cultural Heritage DPCM 2011, thus respecting the principles of minimal invasiveness, reversibility and sustainability.
The project can be classified as seismic improvement intervention since it is aimed at increasing the resilience of the structure to seismic actions without altering the characteristics of its historical evidences.
The intervention, thus taking into account the expectations about the earthquake safety, is made compatible with the architectural, historical and environmental values of the building.
The general aim of the seismic retrofit design is to provide the building with a continuous load path, resistant to the gravity loads as well as the seismic actions, so to avoid the local structural failures.
Apart of local interventions, the global interventions are finalised to achieve the structural integrity, giving to the structure the ability of maintaining the interconnection between the structural chain made up of several links (e.g.: roof elements, floor elements, bearing walls and footings), in other terms the so called box-like behaviour.

Hereinafter the main interventions provided by the structural design are described.

In-plane stiffening by reinforced concrete slab The intervention consists in the realization at the extrados of the vaults of a reinforced concrete slab, made up of lightweight aggregate concrete. The concrete slab is made cooperating with the lateral bearing walls by means of galvanized steel anchors injected with epoxy.

Steel tie rods The metallic ties are designed like traditional connections except for the use of corrosion-resistant material, through a galvanization process. They are applied in the north-south direction on the first floor in order to improve the connections between the vertical structures and vaults, preventing the overturning failure mechanisms of the façade.

Ring beam with Carbon Fiber Reinforced Polymer (CFRP) The CFRP ring beam is placed on the outer side of the building on the second floor level. The intervention is aimed to: i) improve the connection between the horizontal elements and walls and ii) improve the connection between orthogonal walls so as to enhance the three-dimensional behavior of the structure (box-like behavior.)

Stitching interventions with reinforced perforations The intervention is aimed to reconstitute the structural continuity between cross juxtaposed walls built in different eras, by means of reinforced perforations, made of steel rods embedded in cement grouts. The steel rods are designed to be galvanized to prevent the corrosion.

Repointing The intervention has only involved the run-down walls, mainly on the ground floor. The intervention consists of the partial replacement of the mortar joints with better quality mortar, in order to improve the masonry mechanical characteristics. Thanks to the tests executed on the existing mortar it has been designed the mortar mixture very close to the existing one.

Supporting of masonry walls with steel elements The geometric survey pointed out the presence of some irregularities in the elevation of bearing walls. In particular way, some walls of the upper floors interrupt their continuity at ground floor. The weight of these walls is supported by the vaults, that present a crack pattern at their intrados. This irregularity has been corrected by coupling the masonry walls with steel beams, placed at the wall basis. In a such a way the wall is supported by the steel beams resting on the orthogonal walls and the vaults are relieved of the heavy weight.

Local interventions Among the designed interventions there are some other so called local type, e.g.: closing of the niches, new steel lintels, connection of the roof wooden joists to the walls, reinforcement of wall openings.