Abstract

This paper presents the restoration, functional upgrading and plant design carried out at the San Martino Castle, located in Parella. The castle was built in the XIII Century and had undergone extensions and transformations up until the XX Century. It has been recently refurbished with the introduction of new functions. The criteria that drove the plant design were: to give new life to the environment, to achieve adequate comfort levels and air quality; to respect the existing structures, minimizing or integrating terminals and distribution systems; and to install energy efficiency systems, as well as to minimize emissions and running costs.

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Peer-review under responsibility of the scientific committee of the Climamed 2017 – Mediterranean Conference of HVAC; Historical buildings retrofit in the Mediterranean area

Keywords: castle, water-to-water heat pumps; cogenerator; environment integration; monitoring

1. Introduction

Historic buildings form a large proportion of the existing building stock of most European cities. Their refurbishment and conversion involves a series of complex issues that require a balance between heritage conservation, human comfort, energy efficiency, and economic feasibility. First, the insertion of new functions and activities must
be compatible with the historic interest of the building and the natural landscape, without undermining their special aesthetic, historical, architectonic and material values. This issue is more common in countries with the largest built heritage in the world, such as Italy, Spain and the UK [1]. The majority of architectural heritage is public and over 70% of the buildings represent a cost rather than an economic resource [2]. The problem is more serious in private buildings without any access to public funding, although in recent years different crowdfunding programs for arts and heritage have started. Moreover, the lack of funding and investments for the management and maintenance leads to further damage in the built heritage already restored. In Italy, there are 911 sites listed as “excellent heritage value” at the international level by the UNESCO [3] and 704 of them are recognized as “cultural sites”. Furthermore, the Italian Ministry of Culture counted 205,572 heritage sites and 46,025 historic buildings [4], distributed throughout the entire country. In this context, the Piedmont Region ranks fourth in Italy for the number of cultural heritage [4], after Tuscany, Veneto and Emilia Romagna. The cultural heritage of the Piedmont Region consists of 13,289 buildings, divided mainly into churches (1730), houses (1539), palaces (975), castles (579), chapels (444), villas (283), steeple (277) and towers (242) [4]. The number of castles is particularly high, compared to the other Italian regions, thanks to the royal and noble families that characterized the local history. As a matter of fact, there are 3,840 castles in Italy and 15% of them are located in Piedmont and 8% in the province of Torino [4]. Moreover, Torino is one of the most visited cities in Italy from a tour-ism point of view. It ranks fifth in Italy, after Rome, Venice, Milan, and Florence [3]. The Italian database also gives information on use and the conservation state of existing buildings [5]. Unfortunately, it concerns only residential buildings, museums, archives and libraries [6].

Improving energy efficiency in historic heritage, certainly preserving the value and the historical characters, is a topic of great importance. In fact, the European Commission has decided to develop a specific legislative framework to cut CO₂ emissions by 2020 [7], to increase the share of renewable sources [8] and to enhance the energy performances of existing buildings [9]. The European Directives [7] [9] showed the big potential of existing buildings for the achievement of energy savings and CO₂ emissions reduction. Respecting these legislative constraints involves the major acceleration of the energy retrofit of existing buildings, both listed and unlisted. They suggested promoting effective policies for the refurbishment of the existing buildings not only for the construction of a new one with low energy consumptions [7]. Several studies investigated the energy savings related to the refurbishment of old buildings, concluding that it is possible to save between 50% and 68% of the energy consumption by insulating the facades or the roof and replacing the windows [10; 11; 1]. Another important aspect in the Mediterranean area, less studied than the control of heat losses through the building envelope, is related to the control of the internal heat gain and overheating. The literature pointed out the importance of a correct energy audit of old buildings that normally have better energy and environmental characteristics than expected. As a matter of fact, commonly used software for energy labeling and audits tend to overestimate the energy consumption of historic buildings by up to 40% [10; 12]. This situation is due to wrong estimations of the thermal performances, occupants’ behaviors, building operation conditions, and so on [1]. Therefore, the application of inadequate parameters causes disadvantages for these buildings, promoting substitution or energy improvement of components without any real advantage for the global energy balance [10; 11; 12]. To compare different solutions for understanding the economic feasibility of the intervention, the European Commission [9] suggested the use of the cost optimal approach. Heritage buildings must adapt to these changes, physically, socially and anthropologically, within its environment [13]. The protection of a monument can go beyond the original protectable features. In an integrated sustainable use, drives for local and spatial economy, can be expected. A particularly important challenge is related to the economic value of these heritage buildings: the inclusion of new compatible activities should produce an economic benefit overtime. This challenge is particularly important for private buildings, which can be revived only with a sustainable management from an economic point of view.

2. Aims and methodology

This paper presents the restoration, functional upgrading and plant design carried out at the San Martino Castle, located in Parella, a beautiful natural area in the Turin Province (Italy). The building and the natural area are listed. The castle, today owned by Manitalidea, was built in the XIII Century and had undergone extensions and building transformations up until the XX Century. The work has been structured in the following phases: (i) historical analysis of the building related to the technological and morphological aspects; (ii) design project with the definition of the most appropriate internal functions; (iii) definition of possible retrofitting actions on the building envelope; (iv)
definition of possible retrofitting actions on heating/cooling and lighting systems; (v) evaluation of the energy consumption; and (vi) energy and environmental monitoring of the building.

3. Historical analysis of the building

The restoration of the castle started from a profound knowledge of the history of the building and the landscape. As a matter of fact, a deeper knowledge of the history of the building is the first step to identify the needs for suitable intervention [13]. This means understanding the original construction, alterations, actual conditions, qualities, material and immaterial values, lacks, and retrofitting opportunities. In this case, historical and archival analyses were conducted in total absence of previous investigations on the castle. Available sources were mainly related to archival documents (e.g., Fondo San Martino of Parella) and paintings of the heritage site. The historical analysis allowed to build for the first time the history of this Castle. It was built in the XIII Century as a “shelter” or “casa forte”, an old farmhouse. A first extension was built in the XVI century by Alessio I (founder of Secondi di San Martino di Parella) that turned the shelter into a building through a specific project. Carlo and Amedeo di Castellamonte continued this project in the subsequent century. The current architectural shape, the decoration of the facades, as well as the first design of the main courtyard and the garden have been developed in this stage. The indoor and outdoor organization of the castle resembles the Masino castle, near Turin. Similarly, the decorations were done by the same workers of the Castello del Valentino in Turin. In the XVIII century, the Parella castle underwent several renovations, structural consolidations, and decoration remakes, which led to a modern image. In addition, under the guidance of the architect Giacomo Antonio Paracca, a new wing for the noble apartments was built. In 1778, the shape of the castle was defined, as shown by the “Catasto Piemontese” (Figure 1).

![Fig. 1. The area of the Parella Castle in the “Catasto Piemontese”, 1778](image)

Finally, in the XIX century, the castle had new transformations related to the restoration of the decorations and the renovation of the interior spaces. The monument has been maintained in good condition until the end of the XIX century, when it was sold by its aristocratic owners. Then, several spoliations characterized its history. The structure, after having been abandoned for approximately 10-15 years, has been recently refurbished by the new owner Manitalidea, with the introduction of new complex functions such as a hotel, a convention center, a gourmet restaurant, a café, a wine bar, a Spa, and several shops for selling selected products of the territory. Also, in the area, where there were once the “Canavesani” gardens founded by Adriano Olivetti, an agricultural park and a vineyard (Erbaume) will be built based on the principles of environmental protection, respect and the enhancement of the territory and local productions.
4. Architectural design project

The refurbishment of the Parella Castle aims at restoring the architectural and historical character of the building as well as inserting new functions compatible with its historical aspects. Particularly, departing from the historical analysis, the designers decided to show the different construction phases of the building and the decorative artifact by securing its structure. This design project is a key part of a wider tourist accommodation initiative that also involves the historical park near the estate (approximately 60,000 m²) (Figure 2).

![Fig. 2. Parella Castle, external view](image)

The insertion of new functions and features follows the principle of flexibility and adaptability to have less impact on the original building. The activities that require several structural transformations have been placed in areas with a lower presence or absence of architectural elements and decorative values. The hotel and the pub are located in this area. On the contrary, the activities with lower structural transformation requirements, such as the convention center and the public reception, have been inserted in the areas with less flexibility for the presence of heritage values. In general, the insertion of new activities does not require major changes to the original building. Most of the demolitions in the project concern interventions recently built and they are mainly due to the need to adapt the buildings for structural safety. Similarly, a new underground building was built near the “Corte Rustica” to house the electrical and mechanical plant without any impact on the aesthetic image of the heritage site (Figure 3).

![Fig. 3. One of the courts of Parella Castle](image)

At the same time, the energy retrofit aims at reaching high-energy performance levels, as well as preserving and valorizing its heritage values and its original characteristics. From an energy point of view, the project also included a dynamic energy model of the building to define the most appropriate intervention. The as-is state energy performance of the building was modelled using the software EnergyPlus 7.2 to take advantage of the energy behavior of the original building envelope. In fact, its high thickness guarantees good thermal transmittance (U-value) and inertia. The design of the HVAC systems is based on this dynamic model to minimize the energy consumption of non-renewable sources and to avoid oversizing of the plants that could interfere with the building.
Adhering to the European standard [14], the energy retrofit started from the evaluation of the solutions compatible with the building envelope in collaboration with the local Heritage Authorities. The constraints arising from the frescoes in the courts and in the rooms limited the works to the refurbishment and the insulation of the roofs, which were already damaged and the replacement of some windows with low transmittance ones. For this reason, the intervention focused mainly on the systems. Then, high-energy performing technologies for heating and lighting systems were individualized, also maximizing the use of daylight. As often happens in this type of building, insulation of the masonries was not possible. The intervention on the exterior façade was not possible due to the presence of a specific historic characterization. Similarly, the insertion of internal insulation was not possible because of the presence of precious frescoes in the courts and in the rooms. The frescoes were completely restored using traditional techniques.

The existing mixed masonry presents a complex pattern composed of irregular ashlar and a nucleus formed by raw and mixed materials such as igneous rocks, mortar, bricks, and wood. It has a thickness of approximately 0.6 m and it is covered in most parts on both sides with historic lime plaster, wall paintings and frescoes. The typical U-value is 1.7 W/m²K. The original masonry has been consolidated to guarantee the adequate resistance against static loads and failure mechanisms. Particularly, low-pressure mixture binders have been injected to increase the average value of the masonry compressive strength. The lightening of the horizontal elements preceded the intervention to reduce the vertical load and the horizontal thrust, which the elements are subjected to (Figure 4). The damage on the existing roof allowed the insertion of thermal insulation. The original roof was not secure from a static point of view; thus, it has been completely re-furbished with an insulated roof. The new stratigraphy of the roof is composed of: 0.15 m of rock wool insulation material. The U-value is 0.22 W/m²K. The intervention on the windows was not always possible. The existing windows have single glazing and wooden frames with a U-value is 5.0 W/m²K. The air infiltrations are considered to be 78 mc/h (0.1 Vol/h). Just a few windows have been replaced with double glazing with a low-e coating and wooden frames.

5. Plant types and building uses

Before the renovation, the building’s facilities were limited to a small heating system just dedicated to a few rooms and a simple electrical plant. As described before, the building is now characterized by many activities and, as a consequence, many plant types have been realized in order to match the different needs in terms of: thermal comfort, IAQ and architectural integration. The following table connects the main building uses with the plant types (Table 1).
The technical rooms, where mainly pumps and Air Handling Units (AHUs) are installed, are located in the attic, in the basement or in rooms without architectonical values. Pipes and channels have been installed in existing shafts. In many cases, the exhaust air channels are installed within the old chimneys and the intake grill is integrated (Figure 5).

Service rooms (such as toilets and kitchens) have been located in spaces not characterized by architectonical and historical values. In the spaces under the attic and characterized by a wood coffered ceiling (e.g., restaurant rooms and events area) fan-coils have been installed in the attic, preserving the architectonical features of the noble rooms, simplifying the maintenance operations and reducing the sound pressure level. Service rooms (such as toilets and kitchens) have been located in spaces not characterized by architectonical and historical values. The custom-made air vents are installed and hidden within the coffered ceiling. In the hotel, fan-coils are installed within the false ceiling in the passageway within the rooms or in the corridor to not disturb the occupants in case of maintenance (Figure 6).
In the rooms with frescoed vaults, radiant panels and underfloor channels for fresh air have been realized in order to preserve the artistic values (Figure 7).

In some events areas characterized by large crowds, relevant internal height and ceilings without frescos, an entire air system has been realized. In the shops, fan-coils are integrated within the furniture or counter walls hidden from view. In any case, inspection panels guarantee maintenance (Figure 8).
6. Plant efficiencies

The architectural constraints did not allow the realization of a high performance building envelope. In any case, many functions within the building are characterized by high-energy consumption due to the use, for example, to high domestic hot water consumption (in the Hotel and Spa) or high ventilation rates (events areas and restaurant). For these reasons, the focus on energy efficiency surrounds the plants.

6.1. Generation system

Water-to-water heat pumps have been installed for heating and cooling. The thermal source of the heat pumps is an aquifer and the emission system is characterized by low and medium temperature systems to achieve high seasonal efficiencies. The two installed heat pumps are units for simultaneous and independent production of hot and cold water. This way, the thermal energy is a type of heat recovery due to the cooling energy generation, achieving a higher seasonal efficiency. The energy savings is also associated with the high nominal efficiency of the units and their flexible operation at partial load. Thanks to the use of electrical heat pumps, there are no chimneys and outdoor units that could modify the exterior image of the castle (Figure 9).

A cogeneration system was installed for the electricity generation (for heat pumps, lighting, ventilation, etc.) and the thermal energy generation at high temperatures to be used for the domestic hot water production for the hotel, the restaurant and the Spa. This way, high-efficiency can be achieved due to the heat recovery and allowing the heat
pumps to not be required to produce hot water. The technical spaces, where the generation systems are installed, are located in the old stables or storage. In this way, there is no interference with the noble part of the castle from an architectonical, acoustic and maintenance point of view.

6.2. Distribution system

Most of the AHU are equipped with high efficiency cross-flow heat recovery systems except when the distance between the supply air and exhaust air channel was too long or for space reasons. Variable flow hydronic circuits have been realized using pumps equipped with an inverter (Figure 10).

Fig. 10. Variable speed pumps

7. Monitoring and telecontrol

As described in the previous paragraphs, the building is mainly characterized by three levels of complexity:

- Architectural constraints that forced the plant realization in difficult-to-access building areas;
- Heterogeneity of the activities performed within the building;
- Low running costs due to low energy consumption mainly related not to the building envelope, but to the optimization of the facilities management.

A common monitoring platform has been implemented to reduce this complexity. This platform checks all the plants within the building (HVAC, lighting, intrusion alarm systems, etc.). The data unification under a unique interface allows the reduction of the management complexity, the simplification of the plants’ maintenance, and the decrease in time and mistakes when finding alarms and faults. The data exchange between the different plants and subsystems within the building allows the definition of adaptive control strategies to be a function of the actual presence of people within the building, air temperature, and daylight. For example, the disconnection of the alarm systems modifies the indoor air temperature set-point. Moreover, the lighting system is linked to the natural light conditions and thermal mass activation systems provided for thermal/cooling peak shaving. Distributed intelligence control systems have been installed to manage the different facilities and spaces within the building, keeping the benefits of a centralized generation system. The monitoring system is equipped with electrical and thermal measurement devices installed on the main user and electrical boards. This configuration allows the monitoring of the energy consumption with two aims: subdivide the costs of all the activities within the building and allow the continuous improvement of the control strategies (Figure 11).
The case study shows an intervention of an energy retrofit and plant installation in a historic building, preserving the heritage value and optimizing the original energy behavior. The renovation project of the Parella Castle is characterized by several innovations in different fields. The artistic constraints arising from the frescoes limited the works to the refurbishment and insulation of the roofs, which were already damaged. For this reason, the intervention focused mainly on the systems. The realization of high efficiency plants is a must to guarantee low running costs of the facility. The criteria that drove the plant design were: (i) to respect the existing structures, minimizing or integrating the central HVAC systems, the terminals and the distribution systems; (ii) to achieve adequate comfort levels and air quality; and (iii) to install energy efficient and flexible systems as well as to minimize emissions and running costs. Dynamic simulation, commonly used in new, complex and low energy buildings, has been used in this project to avoid plant oversizing, especially in the case of the distribution and emissions systems, minimizing the interference with the historical building. The large number of the activities within the building can be realized by installing different plant types and flexible generation systems to guarantee different comfort and IAQ levels during various period of the day and in several parts of a large building.

References


