

APPLYING DIGITAL TOOLS AS AN EFFECTIVE SUPPORT FOR CONSERVATION RESEARCH AND DESIGN PROCESS: THE ROCCA JANULA CASTLE IN CASSINO, LAZIO

1. INTRODUCTION

Automated testing, construction, inspection, maintenance and repair have become demanding activities in the process of protecting cultural heritage. The revolutionary influence of mechatronics and IT on routine operations is inestimable. The integration of different information and numerical models allows testing novelties related to the use of ICT to create a comprehensive description of the examined cultural object. The data and models can then be used to identify and describe defects and degradation, in particular, to determine a possible reduction in the impact of harmful factors on the object. All purchased knowledge that can be properly applied is input to an automated or a semi-automated decision-making process useful for studying and beyond deciding on the fate of historic buildings and cultural heritage (CHENG *et al.* 2015; BAIK *et al.* 2018).

In connection with these issues, a research period spent at the University of Cassino and in Southern Lazio to become acquainted with the above-mentioned technologies allowed to find a perfect object to implement these tools in the process of renovation and conservation of monuments.

2. CASE STUDY

Rocca Janula castle constitutes the case study, located in Cassino (Lazio, Italy), a city placed in the valley at the foot of Monte Cassino and Monte Cairo (Fig. 1). The castle lies about halfway down the road from the city to the monastery of Montecassino, in a not easily accessible place. The castle is a visually significant element in the city landscape, as it determines its character. In the past, together with the wall surrounding the city, it gave it a character of fortification and defended the entrance to the monastery. That is why its level of aesthetics together with the authenticity of the historical tissue is very important.

It would seem that Janula's name comes from the two-faced ancient god of entrances and gates, Giano (Janula), worshipped in ancient times in Cassino¹. This led many scholars to speculate that at the top of the hill there

¹ The technical description of the object was obtained from the Soprintendenza Archeologia, Belle Arti e Paesaggio per le province di Frosinone, Latina e Rieti.



Fig. 1 – Bird's eye view of the castle (author's property).

was a temple dedicated to this god, but no trace of it was ever found. It is, therefore, more likely that Janula's word is related to its Latin meaning (lat. *janua*, small door); it is speculated that this was the place where the entrance to the Roman city's defence system was located, or that the name referred to the fortress as the door to the monastery because it was the first element to be defeated to reach it.

The fortress was founded between 949 and 967, most probably immediately after 952. Thanks to the next abbot, Gerardo, a pentagonal tower and two other side towers for residential use were erected, the walls were extended and a small church was built. A rebellion of the inhabitants of San Germano took place in 1126. Around 1200 abbot Roffredo de Insula built the walls and since then the fortress has been part of a single defensive system of the city of San Germano, consisting of peripheral walls and towers implanted along the walls at different distances. Even thousands of people could hide in it (PISTILLI *et al.* 2000).

There were many disputes about its possession between the abbots of the abbey, the popes, the emperors and various rulers. The original structure probably contained a square tower in a closed casing and did not coincide with the perimeter of the city wall. This model was widely spread in the area, and used i.e. in the fortress of Monte Trocchio and Roccaguglielma. In this area, the towers were the first elements of the fortifications. The city walls were built according to the morphological conformation of the terrain. Fortresses

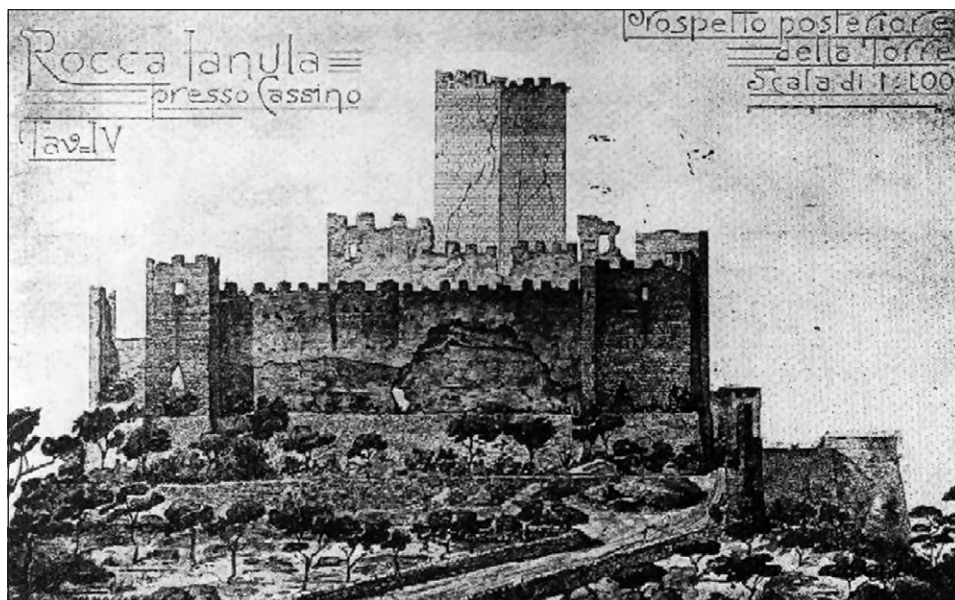


Fig. 2 – Esthetics of the castle in XIX century (from PISTILLI 2000).

of this type were separated from the inhabited area. The residence was limited to supervisory matters and immediate needs in case of sudden enemy attacks.

Such an impressive fortification must have worried emperor Frederick II, who ordered its destruction for fear that such a powerful military structure could serve the enemies of Southern Italy against the Empire (PISTILLI *et al.* 2000). Fortunately, the fortress was not dismantled completely. The reconstruction by the imperial authorities was carried out with typical Swabian architectural elements. In 1349 a violent earthquake destroyed the abbey and seriously damaged the fortress. The monastery was rebuilt around 1357 (Fig. 2). The years between 1378 and 1400 were quite turbulent in a series of battles between the abbey and its neighbouring masters.

In 1806, after the conquest of the Kingdom of Naples, Joseph Bonaparte, together with the Napoleonic decree, reformed the state by closing monasteries and abbeys. The monastery in Montecassino changed its name into a factory and the abbot became its director. Rocca Janula loses its office. On July 15, 1815, thanks to the Treaty of Casalanza, the monastery became again a religious institution. In 1860, after the reunification of Italy, the monastery was declared a National Monument and Rocca Janula and the surrounding lands were transferred to the public domain. At the beginning of the 20th century, the fortress was threatened with demolition because it was not safe for the

city underneath. In 1906, the mayor of Cassino Antonio Martire submitted a request for the repair of the building. Engineer Leonardo Baldizzi was given the task of designing the building. The Second World War aggravated the already fragile situation of the monument by introducing the fortress into the German defence system of the Gustav Line. The clashes severely damaged the fortress, leaving only a pentagonal tower and part of the walls and internal buildings. In 2000, the fortress was the subject of a major renovation that lasted several years and it was reopened to the public on September 25, 2015 (PISTILLI *et al.* 2000).

The only access to the building is located on the western side. The eastern part of the castle has been completely taken out of use because its instability makes it dangerous for the users and it is exposed to further damage. In front of the main gate, there is a two-storey terrace. The remaining walls are located above steep slopes. The castle rooms are used according to the needs of the users. Current guardians of the facility are members of the Corvi di Giano organization. It is a non-profit organization dealing with historical reconstructions. Their performances can be seen not only in Cassino but also in the surrounding towns. The name of the organization is not random. The word “corvi” in Italian means “crows”, a symbol of death and war in western European culture. The second part of the name has its connection with the legend quoted above, according to which the name of the castle comes from the Roman god *Janus*. The facility is open to the public for concerts, fashion shows, book presentations and other events.

3. METHODS AND RESULTS

3.1 *Data collection*

A mixed method was used to carry out the research; it included experimental, modeling and computational approach (NIEZABITOWSKA *et al.* 2014; ŻMUDZIŃSKA-NOWAK *et al.* 2016). The project relied mostly on a photogrammetric survey, supported by additional digital tools and traditional data collection methods. Tools chosen for the process were:

- PENTAX K-3 digital camera fitted, with an 18/55mm lens set. CCD resolutions is 6016×4000px with a sensor size of 23.5×15.6mm;
- Phantom 4 Pro drone with a 4K resolution and the speed of shooting 60fps;
- Creality CR-10 3D printer with printing size 300×300×400mm and filament diameter 1.75 mm fitted with PLA filament;
- Software: Autodesk Revit 2018, SketchUp Pro 2016, Autodesk Autocad 2018, Agisoft photoscan Professional, Autodesk ReCap;
- Measuring tools.

3.2 Methodology

Data collection process started with literature review and archive studies. Multiple background and environmental analyses were created. Secondly, based on the photos taken with the drone, supervised by Giuseppe Masella, a cloud point was generated in the PhotoScan program. It was checked by measuring two test sections in the castle, but thanks to geolocation the correction was not needed. First, the program created the Tie Points model (Fig. 3a) consisting of 249,550 points and then, after manual cleaning of the model, the dense cloud model consisting of 11,708,091 points. The data were then exported to Autodesk ReCap and changed into .rcp file. That file was imported to Autodesk Revit and, based on the point cloud, the model was created in the H-BIM technology (Fig. 3b).

To understand overlapping parts of the structure and highlight them, the H-BIM model was divided into three phases: Before restoration in 1996, Existing building, Proposal (BACCI *et al.* 2019). To complete the model, new BIM families were created such as irregular wall structures. Then the model was exported to Autodesk AutoCad to be transformed into .stl files. Due to technical issues with objects, it was replaced by SketchUp Pro 2016 in which the files were exported to desired format (Fig. 3c).

3.3 Results

The model allowed us to learn the exact proportions and dimensions of the castle. Thanks to collected data it was easy to determine that the fortress has undergone many changes since its foundation. Damaged by numerous earthquakes and wars and rebuilt many times, it has a structure of not entirely clear origin. On the other hand, the representation of the historic and constructive evolution, with all its data embedded in one single model, has produced very good results in order to roughly interpret the evolution through the heritage virtual model. Thanks to the specific methodology, it was possible to unify the information that was spread out around different archive data and photogrammetry results (CHENG *et al.* 2015) (Fig. 4). As a result of the analysis, the conservation value of the object divided into specific categories could be determined (TAJCHMAN *et al.* 2014):

- Authenticity: fragments of the original medieval structure of external and internal walls are still visible.
- Integrality: during World War II, the external walls were destroyed and the internal defects, during the latest intervention, have been supplemented with new tissue, which enables the reading of the original form of the work. The tower has an original, but incomplete tissue.
- Historical and scientific value: in the context of the location and history, i.e. the place of important warfare and the fortress defending the monastery

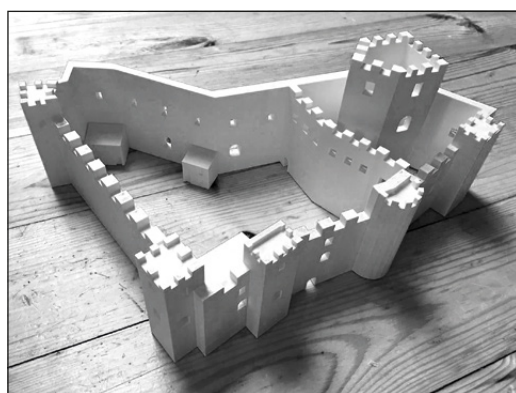
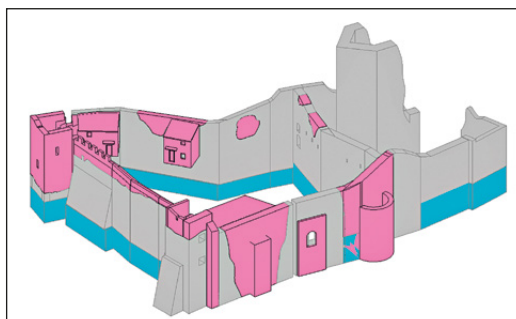
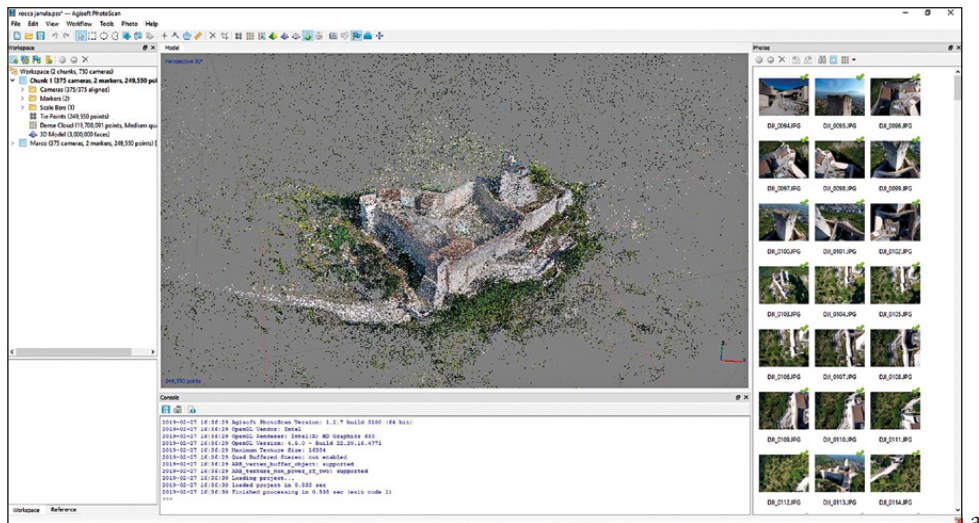


Fig. 3 – a) View of the model in PhotoScan in Tie Points model (249,550 points); b) view of the model in Revit in H-BIM technology with highlighted layers; c) printed 3D model of the castle in the state from XIX century.

DATE	X - XI	XII - XIV	XV - XIX	XX - XXI
STRUCTURE				
IMPORTANT EVENTS	- PROTECTING THE HILL FROM SARACENS AND LONGOBARDS - EARTHQUAKE	AFTER THE BATTLE OF SUBI, GREGORY VIII WAS IMPRISONED HERE - SAN GERMANO FOR THE CAUSE OF JUSTICE - RECONSTRUCTION BY FREDERICK II - EARTHQUAKE	THE STRUGGLE BETWEEN THE ARAGON PEOPLE AND THE ANGEVINS PEOPLE - CONSTRUCTION OF A NEW ROAD FROM SAN GERMANO TO GROSSETO - THE ASSASSINATION OF THE KING OF ARAGON - THE ASSASSINATION OF THE KING OF ARAGON	WORLD WAR II AND THE BATTLE OF MONTECASSINO - THE RENOVATION AND OCCUPATION OF THE FORTRESS BY THE CORVI DI GIANO ORGANIZATION
FUNCTION	DEFENSIVE FORTRESS	CITY FORTIFICATION SYSTEM	DEFENSIVE FORTRESS NATIONAL MONUMENT	DEFENSIVE FORTRESS TOURISTIC PURPOSES
CONNECTIONS				
PROBABLE CHANGES TO THE STRUCTURE				
	AROUND 952 - THE FOUNDING OF A FORTRESS BY ABBOT ALGERIN	1200 - CONSTRUCTION OF WALLS BY ABBOT ROFFREDO DI INQUA	1418 - CONSTRUCTION OF TWO TOWERS ON THE TOWN HILL BY ABBOT PIERRO TOMACELLE	1996 - DAMAGE TO THE FORTRESS DURING THE BATTLE OF MONTECASSINO
	1084 - ERECTION OF A PENTAGONAL TOWER AND CONSTRUCTION OF A SMALL CHURCH BY ABBOT GERARDO	1229 - CONSTRUCTION OF A WALL INSIDE THE WALLS BEYOND THE FORTRESS INTO TWO COURTYARDS	AROUND 1490 - A THREAT TO THE SAFETY OF THE CITY	1996 - 2000 - RENOVATION UNDER THE DIRECTION OF THE ARCHITECT CARLO SCAPITELLI
	WALLS FROM 10TH CENTURY	A TOWER ERECTED IN 1084	THE WALLS FROM 1200	INTERNAL WALL 1229
			TOWERS ADDED IN 1418	ELEMENTS ADDED DURING THE RENOVATION IN 1996

Fig. 4 – Case analysis.

in Montecassino from the Middle Ages, has undeniably entered the history of the country and the world. It is an important place for remembrance and heritage. Thanks to its partially preserved authenticity of form and preserved elements found during excavations, the object is a kind of time capsule. The building is also of didactic importance for its history. The functional arrangements, the visible construction of the walls, documenting the style of the architecture of Lazio, are remained almost preserved.

– Historical and emotional value: since the Middle Ages the monument has played an important role for the residents. First by defending the monks of Montecassino and then the inhabitants of San Germano, by protecting them with walls and ensuring their safety. Today, it is a symbol and a carrier of collective identity for the Corvi di Giano. It is not only a place for social meetings, but also a place for the development of the passions and hobbies of the members of the organization who represent the culture of medieval Italy, and not just in these areas.

– Usable value: the building in its present condition has a high usable value, but insufficient for comfortable use. However, it has an enormous potential and a chance to become a touristic center and a new home for its keepers.

4. DIGITAL DATA MODELING APPROACH TO DESIGN PROCESS

Based on the guidelines mentioned above a functional program was created. The first step in the design process was the delimitation of the area, carried out on the analysis of external conditions. Impact on the scope of the analyzed area had the shape of the terrain and the location of the access road in relation to the castle. The next stage was to solve the problem of communication, resulting in the integration of a facility with a town and a monastery on Montecassino. The proposal is to create a gondola railway with a starting station at the foot of the hill, a second station on the terrain and the final one close to the monastery. This solution ensures easy transport from the city and merges the two most important cultural heritage objects in Cassino. The third phase was separating the interchange zone with a railway station and a rental company. The main pedestrian route has also been marked out (Fig. 5).

The analysis of the existing state allowed to formulate guidelines for the functional system of the object. The concept assumes the division of the object according to the nature of the intervention. Three types were distinguished: Internal, External and Fillings. The Internal are characterized by the placement of structural elements inside the existing tissue and are a self-contained structure, not related to the object. The External ones are the supporting structures, protecting the building elements. The Fillings fill in existing elements, such as defensive walls. The chosen solutions also aim to connect the divided parts of the building.

The central part of the proposed design solutions is the roofing of the main courtyard (Fig. 6a). Such structure would allow increasing the usable area of the building without adding additional buildings, at the same time giving the possibility to regulate the temperature inside the fortress. The designed roof minimally interferes and is not structurally related to the existing tissue. Three sizes of parabolas have been determined, where the largest contain structural elements and drainage of water from the roof, medium size signal the location of important places in the object, such as training areas or rest zones and the smallest being a source of shade and binding the two types mentioned above. The structure is made out of glued laminated wood with polyurethane coating (Fig. 6b). Skylights mounted on aluminium frames have gutters for draining water from the roof. Water is collected in tanks and then partly drained from the object and partly used to water plants in the garden (Fig. 7).

The spiritual dimension of the project is a path consisting of seven spatial frames presenting selected stages from the existence of Rocca Janula. The frames are shaped by both existing and added elements. The first visual frame is the entrance gate which represents the moment of the

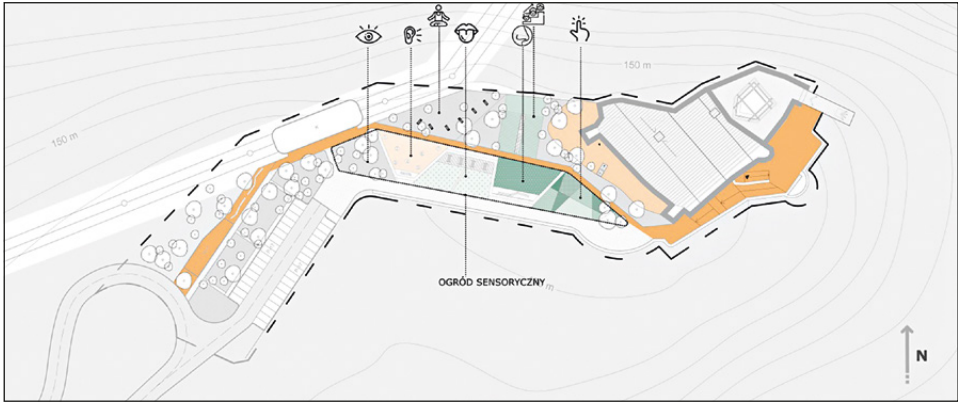


Fig. 5 – Third stage of urban plan creation.

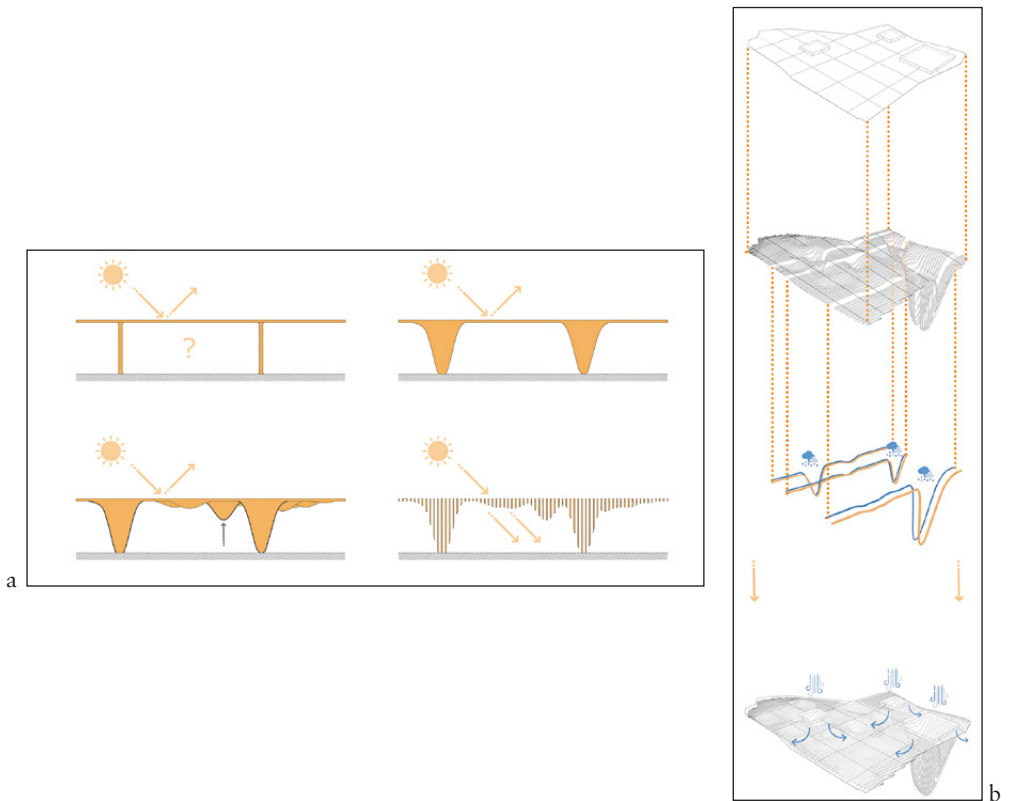


Fig. 6 – a) Steps of creating the shape of the roof; b) Scheme of the roof functioning.

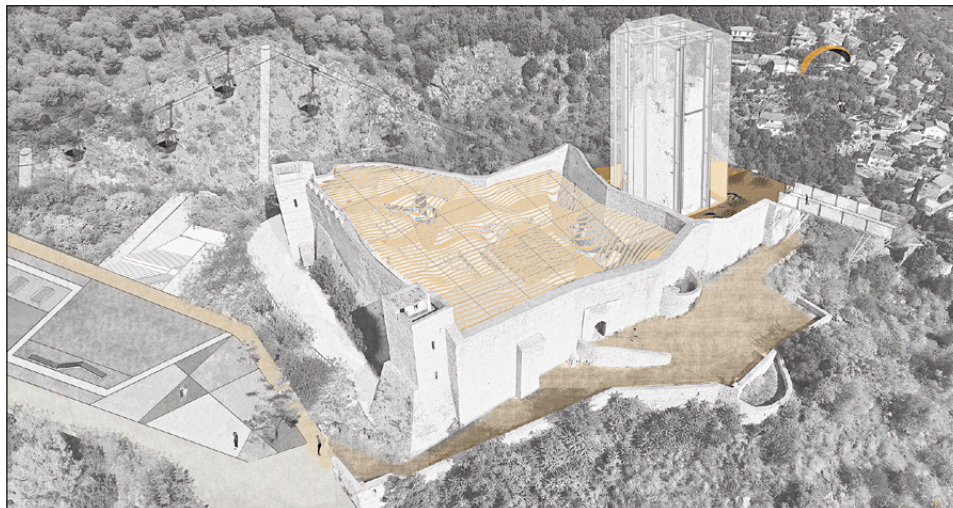


Fig. 7 – Visualization of the castle.

fortress creation. The second is the glazing above the underground part of the former chapel, showing the place where the local population was protected during earthquakes and attacks. The third is the added frame with a hanging canvas, representing the stages of development. The fourth one is the frame leading through the history of the construction of the tower (the oldest preserved element of the object). The fifth one, printed on glass, shows the once existing walls of the place that surrounded the city at the foot of the mountain. The sixth is a picture of the warfare conducted in 1944 in the castle. The last, seventh frame depicts horror and war damage, showing a ruined city. It reminds us the horror and the tragic consequences of any military action.

5. CONCLUSIONS

Digital survey tools used in this research let to come up with the data system and helped to formulate conservation guidelines. The idea was to create a simple solution that would reintegrate the fortress into social life. The designed roof above the main courtyard is both a modern sculpture and a practical element which gives more useful space in the object as well as creates shadow and helps to collect the rainwater. The castle is a very important example of medieval cultural heritage for Poland and Italy that connects past of both countries. As a monument of bravery and a shelter through many centuries it should be protected and kept in its best condition.

Several technical issues were found especially in the modeling stage such as limited possibilities of Revit to connect elements with complicated structure. The key step turned out to be creating new families with specific parameters. However, the database should be expanded and supplemented by additional information. The division into phases was an important step in further analytical work especially formulating conservation guidelines. For the future works more phases could be implemented into the methodology to clarify more the changes that the object overcame.

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ABSTRACT

The paper deals with the very extensive and complex topic of the conservation and adaptation of the medieval defensive castle of Rocca Janula in Cassino for the headquarters of the non-governmental organization Corvi di Giano. The castle is a very important building due to its location and its history. Its location makes it one of the two landmarks of the city's landscape. Due to its connections with the Montecassino Monastery, it has a great cultural significance for Poland and Italy. The research described in this paper is an attempt to re-integrate the fortress into social life. The project is an example of the application of digital recording methods such as photogrammetry, HBIM technology and 3D printing. The integration of these methods allowed creating a database by which valorization practices were implemented and conservation guidelines were formulated.