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Geophysical investigation at the Castle of Ceglie Messapica (Italy)

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Abstract

The castle of Ceglie Messapica was originally born as a fortification – a lookout point. According to some hypotheses, the construction of the central core, consisting of a Norman tower alongside the square tower that was built in the following centuries, dates back to around 1070-1100. The first family to live there was the Pagano family.

The castle was abandoned for several years, and a restoration project was presented in 2019. Before the restoration, geophysical investigations were carried out to identify the presence of metal reinforcement bars in the structure of the castle. 58 corbels were analysed using Ground – Penetrating radar (GPR), method. GPR data were acquired along parallel profiles 5 cm spaced using the Ris Hi-Mod georadar system with the 2000MHz antenna. GPR data were processed in a 3D mode using Gpr-slice software. Results well evidenced the 3D distribution of the metal bars and their advanced corrosion that causes stability problems.

Keywords: ground-penetrating radar, restoration work, castle.

1. Introduction

The Castle of Ceglie Messapica (Province of Brindisi, Italy) (Fig. 1) is a medieval defensive structure of the ancient city, starting from the central nucleus of the Norman era over the centuries it has been remodelled and expanded several times. Together with the Collegiate Church, it dominates the medieval village being located at the highest point of the hill on which the municipality is located.

There are not many documentary traces of the Castle. For example, it is not mentioned in the *Statutum de reparatione castrorum* of Frederick II of Swabia (Fonseca, Conte, 2010). The castle was originally built as an observation tower by the Normans from which one can observe a vast territory up to Brindisi and Taranto. The construction of the Norman Tower, next to which the square tower was built in the following centuries, dates back according to some hypotheses to around 1070-1100. The first family to live there was the Pagano family. The walls of the Tower are built using the folio technique. The wall is made up of deformed blocks of local limestone not plastered and is double, with an interspace of crushed stone and waste stone cemented in bole.

Between the 12th and 13th centuries, under the Swabian and Angevin dominations, the castle was first expanded with the construction of additional fortifications, including the 3 circular towers. During this period, various families succeeded one another at the helm of the castle. In 1484, the castle passed to the Sanseverino family following the marriage between a member of the family and a member of the Dentice family. The Sanseverinos are certainly the family that has most influenced the history of the Castle and the town. The Sanseverinos purchased the fiefdom

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from the Curia of Brindisi between 1361 and 1368. It was they who gave the castle a more noble appearance, promoted the construction of the 34 m high square tower in the 15th century and favored the feudal lord Aurelia Sanseverino, the arrival in the city of some monastic orders (Fonseca, Conte, 2010).

Fig. 1- The castle of Ceglie Messapica (Province of Brindisi, Italy).

The tower recalls other similar structures in Puglia and Basilicata from the same period. A square-shaped tower, decorated with battlements in symmetrical formation.

The rooms are divided into three floors and it is finally equipped with a well and underground rooms with the function of a cistern or food storage. The dating of 1492 reported by Cosimo De Giorgi and then by Primaldo Coco referring to an inscription on the castle is incorrect. In reality, the inscription is '1602' and refers to the year in which all the current buildings overlooking the courtyard were present, including the door on which the inscription in question is placed (Fonseca, Conte, 2010).

The Sansevirino family left the fiefdom in the early 17th century. After brief interregnums in 1624 the fiefdom was ceded to the Lubrano family, who in 1641 obtained the title of Duke on the fiefdom of Ceglie and from them after a few generations it arrived through the marriage between Caterina Lubrano and Luigi to the Sisto y Britto family.

The families that followed did not manage to leave a mark comparable to the legacy of the Sanseverinos. The families continued to increasingly restrict the assets of the fiefdom.

The last feudal families alternated in the 19th century when the Castle passed from the Sisto y Britto to the Neapolitan family of Verusio. The Castle came to the Verusio as a unicum. In the first half of the 20th century, the castle was divided into several parts according to the hereditary axis. Thus began a phase of decline for some portions of the Castle.

Fig. 2- Geophysical campaign: acquisition phase (photo by Author, 2019).

The descendants of the Verusio family decided to no longer live in the castle, part of the family returned to Naples.

The result was the transfer of the furnishings, the abandonment of some of its parts and a serious structural deterioration that caused, among other things, the collapse of the roofs and coverings in many areas.

The Council Room was also involved in the collapse, where a completely painted wooden false ceiling was lost. It was precisely these abandoned parts that the municipality took charge of with an initial intervention of structural consolidation of the Torre Quadrata, which at the time was not yet municipal property, in the 1980s and subsequently starting from the end of the 1990s.

Since the last years of the twentieth century, the municipal administration has begun to acquire portions of the Ducal Castle, the last acquisition dates back to 2014 when the Norman and Square Towers and the adjacent areas became municipal property.

In 2019 a geophysical campaign was undertaken to help the restoration work (Fig. 2). A three-dimensional georadar survey was carried out using a pulsed Ris Hi-Mod (IDS) GPR (Ground Penetrating Radar), equipped with a 2000MHz antenna. The investigations aimed to identify the possible presence of metal reinforcement structures inside 58 corbels (Fig. 4).

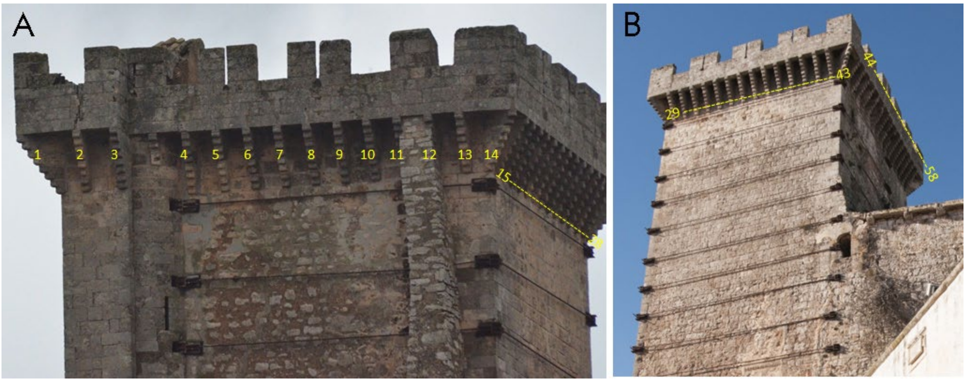

Fig. 3- The castle of Ceglie Messapica. Numbering of corbels: A) Northeast and Southeast sides; B) Northwest and Southwest sides (authors, 2024).

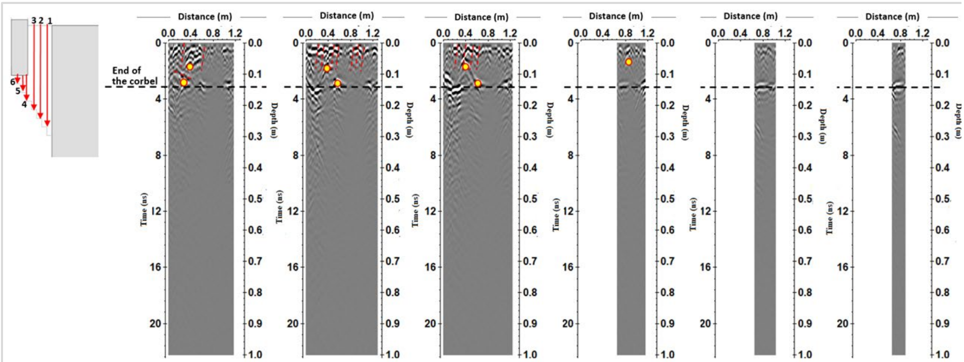

Fig. 4- The castle of Ceglie Messapica. Numbering of corbels: A) Northeast and Southeast sides; B) Northwest and Southwest sides (authors, 2024).

2. GPR data acquisition and interpretation

GPR data were acquired on 58 corbels using a geometry of acquisition which involves the creation of equally spaced parallel profiles of 0.05m. The time window was set at 30 ns and were acquired 512 sample per scan.

Other acquisition parameters were set directly in situ according to the response of the electromagnetic signal. As regards the georadar surveys, the quality of the data acquired during the measurements was good thanks to a series of measures adopted in the acquisition phase. However, to eliminate a noise component, which was still present in the data, and to facilitate its interpretation, an elaboration of the acquired profiles was carried out, the steps of which are listed below (Conyers, 2012):

1) background removal filter: this type of filter allows the removal of the horizontal band visible in the radar sections, which can represent reflections from objects that remain at a constant distance from the antenna. The algorithm, based on a simple arithmetic process, which adds all the amplitudes of the reflections generated at the same time along the profile and divides by the number of the added tracks, allows the average track removal and thus enhances the non-horizontal events present in the radar sections;

2) low pass filter: allows to elimination the high-frequency noise component (fog effect) present in the radar sections

3) migration: a technique that allows to elimination of distortions introduced in the recorded data. a GPR section does not contain

unidirectional information due to the conical radiation lobe of the energy, so some reflections present can also be generated by objects placed laterally with respect to the position of the antenna. This multidirectional character of the recording of GPR reflections manifests itself in the generation of hyperbolas that can cause serious problems in interpretation. Migration solves this image problem by bringing the energy back to its true reflection point.

Subsequently, the anomalies present on each 2D radar section were correlated using the analysis of the amplitude of the reflected events within assigned time intervals (time slices). This type of analysis gave satisfactory results that facilitated the interpretation. Amplitude time slices were

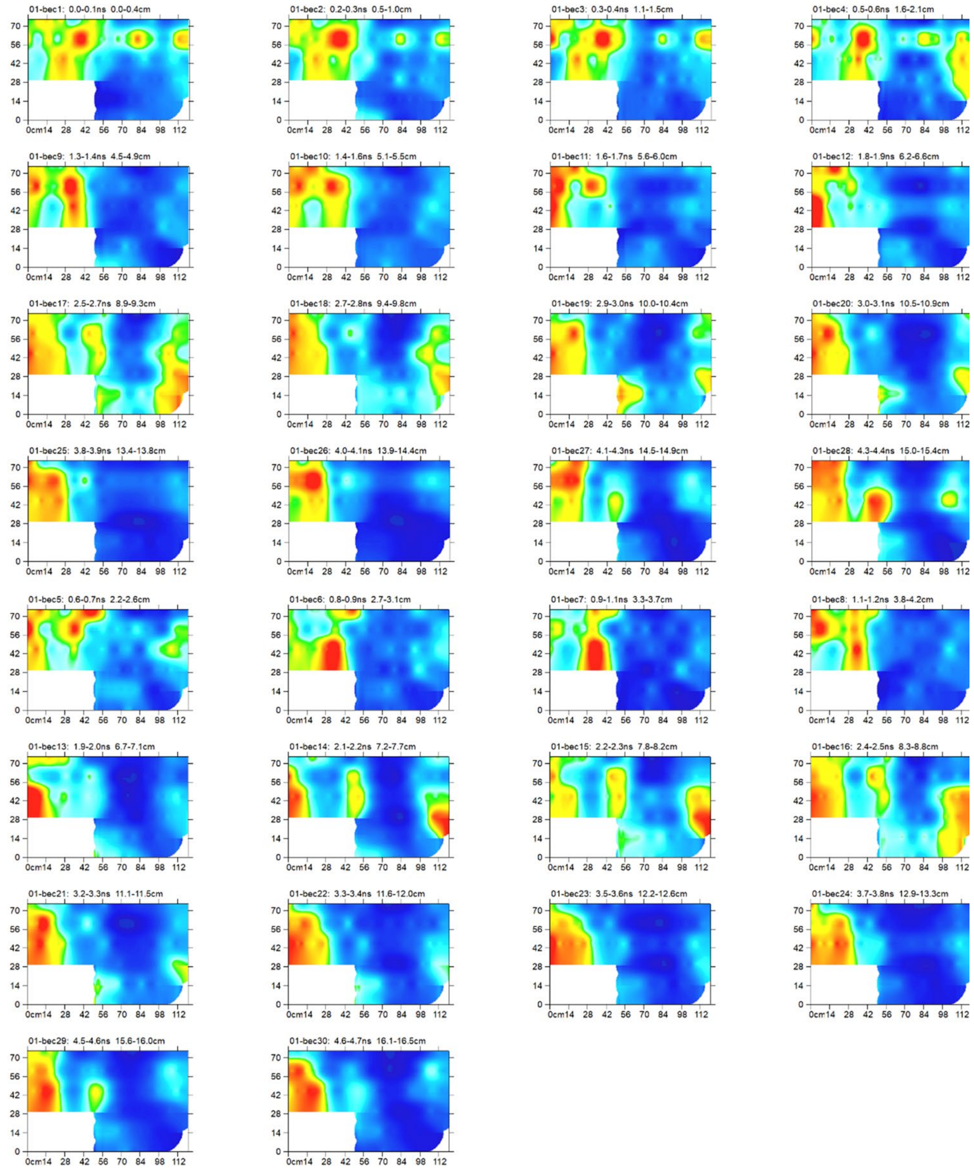

Fig. 5- Acquired data: the time slices (authors, 2024).

therefore constructed at time intervals of 0.2 ns, so that each slice corresponds to a thickness of approximately 0.011 m. The blue colour indicates the weak amplitude of the reflected signal (substantially homogeneous material); the colours from light blue to the most intense red indicate variations in the amplitude of the reflected signal and therefore the presence of significant electromagnetic discontinuities. The variations in amplitude (therefore in colour) in the same slice are indicative of horizontal variations in the electromagnetic characteristics of the medium investigated (Conyers, 2004; Conyers, 2006; Leucci, 2019; Giannino and Leucci, 2021).

The GPR data analysis showed a good penetration of the electromagnetic signal that allowed us to investigate the entire thickness of the corbel. This thickness is of the order of 15.0 cm approximately, considering an average propagation speed of the electromagnetic waves equal to approximately 0.1 m/ns. In particular, the profiles highlight (Fig. 3):

• some events reflected by the characteristic hyperbolic shape (yellow dots) related to the probable presence of metal reinforcements;

• a series of reflected events (linked to a possible diffraction of electromagnetic energy (red dotted lines) probably corresponding to internal micro-fracturing.

In fig. 5 the amplitude time slices are reported. In them, it is possible to identify the probable presence of three metal elements (black dotted lines) at depths between 4.5-4.9 cm and 14.5-14.9 cm. The poor state of conservation linked to the presence of a series of important fractures is also highlighted (high amplitude events ranging from yellow to red.

3. Conclusions

Geophysical investigations conducted on the 58 corbels show a situation of advanced degradation. The distribution of the metal structures does not appear to follow a regular geometry. All the probable metal structures appear to have caused a swelling inside the masonry constituting the corbels. The presence of numerous fractures and voids is highlighted. The following tab. 1 summarises the probable location of the metal structures concerning the GPR results. The results of the GPR survey were useful for the restoration project which included the identification and replacement of the metal reinforcements.

Tab. 1- Location of probable metal structures.

Corbels	Probable number of irons	Depth position (cm)
1	3	4.5-4.9 e 14.5-14.9
2	2	4.59-4.69 e 11.33-11.43
3	3	3.1-3.5 e 14.5-14.8
4	2	1.8-2.9 e 8.0-9.2
5	2	4.1-5.3 e 11.5-12.7
6	2	2.3-3.5
7	2	5.4-6.4 e 12.7-13.8
8	2	6.9-7.3 e 9.0-9.5
9	2	5.5-5.9 e 9.8-10.2
10	3	4.7-5.1 e 11.9-12.3
11	2	4.3-4.7 e 1.2-1.6
12	2	4.7-5.9 e 9.4-10.5
13	2	5.1-6.1 e 11.7-12.7
14	2	2.3-2.8 e 4.7-5.2
15	1	7.0-7.4
16	1	7.4-7.8
17	2	7.4-7.6 e 14.8-15.0
18	2	5.7-5.9 e 14.5-14.6
19	1	5.7-5.9
20	1	11.0-12.0
21	1	3.9-4.1
22	1	4.5-4.7
23	3	6.6-6.8, 13.1-13.3 e 14.1-14.3
24	3	3.9-4.3, 11.2-11.6 e 14.3-14.7
25	3	1.7-2.8, 6.4-7.5 e 11.8-12.9
26	3	3.2-4.3 e 7.5-8.6
27	2	4.8-5.8 e 8.1-9.1
28	2	3.1-4.1 e 7.7-8.7
29	2	1.5-2.6 e 3.9-4.9
30	2	4.4-5.7 e 7.7-9.0
31	4	1.9-2.9 e 4.4-5.4
32	2	5.2-6.2 e 7.7-8.8
33	2	3.7-4.7 e 10.3-11.4
34	3	4.5-5.6 e 13.3-14.4
35	2	5.2-6.2 e 11.4-12.4
36	1	3.2-3.9
37	2	1.7-2.1 e 14.8-15.3
38	2	4.3-4.6 e 8.9-9.3
39	3	1.5-155 e 11.8-11.85
40	2	1.5-1.9 e 7.3-7.7
41	2	3.5-3.9 e 5.0-5.4
42	3	3.4-3.9 e 6.9-7.3
43	3	1.5-1.9, 3.1-3.5 e 4.6-5.0

44	2	0.5-0.9 e 3.8-4.3
45	2	1.9-2.4 e 4.7-5.2
46	2	0.4-0.7
47	1	5.6-6.0
48	2	0.9-1.3 e 6.0-6.4
49	1	4.6-5.0
50	2	1.3-1.7 e 6.0-6.4
51	2	3.0-3.4 e 4.3-4.7
52	1	12.9-13.3
53	2	3.4-3.9 e 7.3-7.7
54	1	6.0-6.4
55	1	6.0-6.4
56	2	1.9-2.4 e 5.6-6.0
57	1	5.8-6.2
58	2	4.7-5.2 e 13.5-14.0

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