Principles and technologies of historical structures consolidation, case study of Banloc castle complex

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Abstract. Historical monuments (palaces, churches, protected urban areas, so on) are integral part of the national cultural heritage which need activities and measures to protect them. The Banloc complex, located in the west of Romania, encompasses five buildings: the castle, the hunting pavilion, the kitchen, housekeeper house, and the stall. This study involves historical, architectural, structural and physical-chemical investigations with the aim of finding the correct restoration solutions, in good agreement with the Venice Charter, respectively the Nara Charter. Being affected by time and by the seismic sequence (Mw 5.6), the restoration of the building is absolutely necessary for recovering the functionality, structural solution and highlighting the artistic elements. Some analytical techniques, as: X-ray diffraction (XRD), Wavelength Dispersive X-ray fluorescence (WDXRF), optical microscopy (OM), and zoom microscopy, Infrared spectroscopy Fourier Transformed (FTIR), and Raman spectroscopy, have been used in this paper in order to clarify the main aspects about the structure, composition and morphological of the samples collected from Pavilion building. The oxides composition, and the possible organic impurities has been identified by WDXRF amd FTIR/Raman spectra, respectively. The microscopy images revealed the colours, fissures, cracks and even holes due to the time weathering processes, and damages they suffered in time.

1 Introduction

The identification of the subject as a work of art is the limit preceding its recognition as a historical monument [1]. Historical monuments are an integral part of the national cultural

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heritage and are protected by law. Activities and measures to protect historical monuments are carried out in the public interest, on various type of heritage structures, such as palaces [2], churches [3], protected urban areas [4] and others.

The ensemble from Banloc is inventoried in the List of Historical Monuments from Timis county at number 154 with the identification code TM-II-a-A-06177.01; at number 156, the park is located with the identification code TM-II-a-A-06177.02.

The goal in restoration is to preserve the monument as a witness over time and to continue as a work of art [5].

The Banloc ensemble must be viewed through the lens of the Venice Charter of 1964 [6], in accordance with art. 1, not as a singular register, but as a unitary whole, which relates to the park and its surroundings, which confirms the historical events, as well as the significant progress from the glory years of the complex, during which it belonged to the Karatsonyi family and later to Princess Elisabeta of Romania, who became the queen of Greece. A succession of concerns that would enliven the place, by allocating the social custom (art. 5), would facilitate the preservation of the edifices as a whole. The monument cannot be separated from the place where it is located and its history (art. 7). In order to obtain a visual and narrative logic from the point of view of the restoration, the ensemble must be viewed from the perspective of the park's relationship with the buildings belonging to it, through the reconversion attributed to the whole, all of this viewed from a historical, architectural and, not least, aesthetic point of view. The meaning of the restoration is the regeneration of the historical and aesthetic sense of the edifice declared a historical monument and is substantiated by genuine historical acts (art.9). Regeneration closes where the presumption is initiated [7]; the mandatory interventions that are imposed, due to contemporary needs, will stand out distinctly from the structures of the buildings in the complex, in a modern style, without trying to replicate the mansion or the pavilion. The meaning of regeneration is not architectural stylistic homogeneity (art. 11) [6].

Regeneration does not falsify historical attestations (art. 12.). This postulate from the Venice Charter emphasizes the importance of integrating the interventions as a whole, but at the same time they must be distinguished from the initial version. The restoration process is carried out conscientiously in order to maintain the perfection and completeness of the monument (art. 14) [6].

The studied area is located in the southeast of Europe, in Romania, in the south-western part of the country, Banloc commune, in the south of Timis county, at a distance of approximately 48 km from the municipality of Timisoara (Fig. 1). Currently the complex is non-functional, the mansion and adjacent buildings are unused.

Fig. 1. Banloc localisation.

2 Historical overview on Banloc

The municipality of Banloc is attested for the first time in May 1400, when the name "Byallak" was reported in a document provided to the clerk of Cenad. For almost two centuries (1552–1716) Banloc was the summer residence of the Ottoman pasha of Temesvar Eyalet. In 1716, the Banat region, where Banloc is located, was conquered by the Austrians and, in the census of the year later, the municipality was registered as “Panloch” in the district of Ciacova with 85 inhabited houses. In 1759 the construction of the castle of Banloc was completed. The castle is the most important monument of the municipality. It is a massive building with a "U" in-plane shape built in the early nineteenth century. The main façade faces south, while on the opposite side the two wings border a terraced courtyard.

The castle is composed of very heavy perimeter brick and internal walls having thickness of 0.90 m and 0.80 m, respectively at ground level.

The first owner who could be thoroughly researched and who essentially had the main role in the history of the mansion and the community of Banloc, is the Karatsonyi family; they raised the level of the estate from a summer residence to a permanent residence, where they were invited politicians, important artists of the time (Liszt Ferencz), they were great admirers of English and French architecture, they had an attraction for art, for thoroughbred horses, had a luxurious lifestyle, but were known and admired for their generous nature.

Through the investments on the own properties in the Banloc area, a small industry was developed in the bordering region, which included: the spirit factory, the rice mill, the glass factory, the timber factory; they introduced the narrow gauge railway, all of which also contributed to the well-being of local communities.

The Banloc mansion is particularly known for the fact that the last owner was Princess Elisabeta, who intervened in the whole of the mansion, preserved the area of the French formal park, reintroduced thoroughbred horses in pretentious stables, leaving her mark on the mansion and around.

The Banloc Complex is located in the center of the commune and represents a considerable percentage of planted area. It is a perimeter with easy access, being located on the connecting corridor with the city of Deta, with regular and rectangular shape, with an area of the entire land of approximately 10 ha [8].

As one of the emblematic historical monuments from Romania, the Banloc complex (Timisoara) includes five buildings: the manor, the kitchen, the stall, the hunting pavilion and the house of the housekeeper.

Historical monuments are an integral part of the national cultural heritage and are protected by law [7]. Activities and measures to protect historical monuments are carried out in the public interest. The present paper focuses on the Pavilion building, which is part of the Banloc Complex, in which consolidation solutions and chemical investigations will be addressed, followed by the proposal of restoration solutions.

3 The seismicity of the area

Located in the southern part of Banat seismic region (BA), at the Romanian border with Serbia, Banloc withstood in the past century a series of moderate to strong seismic sequences. Some of the the most significant sequences that were documented in this area have occurred in 1915 and 1991 with magnitudes up to Mw 5.6 according to the ROMPLUS seismic catalogue [9] and [10]. Until today, the Banloc earthquake, which occurred on July 12 1991, is considered to be part of the most important seismic sequence of BA. The earthquake had a maximum magnitude of 5.6 Mw, at a depth of only 12.6 km with an estimated intensity in the epicentral area of I=VIII (on the MMI scale). The epicentre of this main shock was located just 3 km from the Banloc castle complex. Just a few hours away after the mainshock, a significant aftershok of magnitude Mw 4.6 occurred. The events epicenters were located on the Banloc-Buzias strike-slip fault system oriented NNE-SSE [10]. The stress field then shifted along the Medja-Gataia fault [10], leading to the occurrence of the December 02 1991 earthquake with magnitude Mw 5.5, at a depth of 7.9 km, in the Voiteg area (only 8.8 km away from Banloc castle complex).

Following the data in the ROMPLUS catalogue [9], the seismic sequence extended for a considerable period of time. In Fig. 2. we have plotted 286 events with a magnitude range $2.2 \leq M_W \leq 5.6$ on a time period of one year.

Typically, the effect of the vertical component of earthquake ground motion on constructions has been ignored in the current studies of Earthquake Engineering. Gioncu and Mazzonlani have developed an important research activity concerning the influence of ground motion vertical component for the load-bearing masonry structures in the Banat seismic region [11, 12, 13]. In particular, the seismic design and assessment of Unreinforced Masonry (URM) structures is limited to the effects of the horizontal accelerations, neglecting the vertical component of the design ground motion [14, 15, 16]. The damages caused by disastrous earthquakes highlighted the brittle behavior of several structural systems especially under seismic actions characterized by not negligible vertical components, which produced significant effects in cases of near-field events.

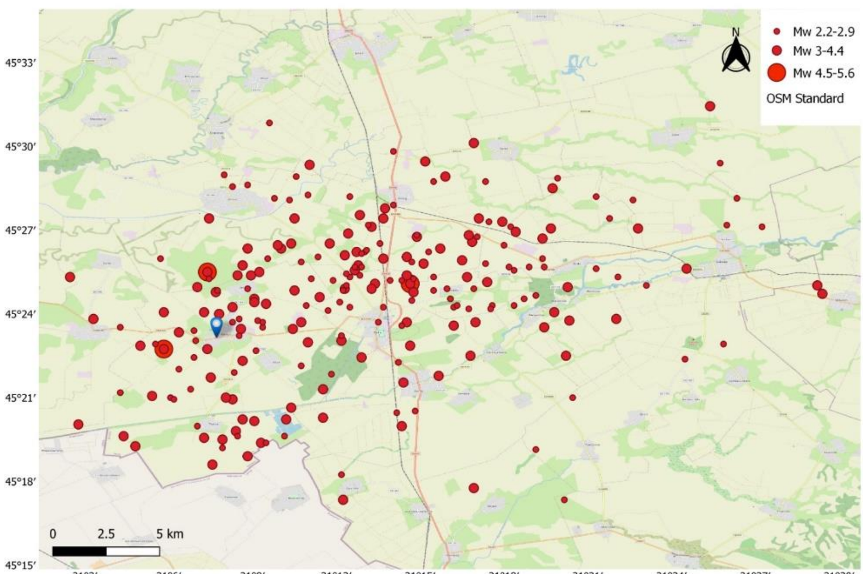

Fig. 2. Seismic sequence of Banloc-Voiteg from 1991.

4 General presentation of the building

In the middle of the park, on the highest level, is the Hunting Pavilion, an elongated octagonal building on the north-south axis, on two levels, in an eclectic style with predominantly neoclassical and baroque influences, with a wooden frame and tin covering, built in around 1870, with a footprint of 123 square meters and a height of 9.30 meters. Compared to the Mansion and the other buildings in the park, this pavilion stands out not because of its scale, but because of the attention to decorative details added specifically to distinguish it. The facades are symmetrically decorated with molded and repetitive ornaments, in neo-rococo style. The main facade with the entrance impost, the rosette, the two imposing pediments to the west and east, and the engaged Ionic columns with volutes and garlands, located in a repeating register on all the facades, give the building both its overall importance and the idea of a monumental staircase. The building has two levels; on the ground floor there is an access through the facade from the East, and an access from the North; on the inside, the part has three enclosures: the one with access from the East is the largest and has, in the southern extremity at 1/3 of the length of the room towards the South, two circular cast-iron pillars, 3.80 m high and 200 mm in diameter, are placed in the center. Above them rests a metal beam embedded in the slab and at the ends in the East and West walls. Through the access from the North, a hall-type room with a staircase that once accessed the first floor is accessed; currently, from this room, through a 20 cm thick wall, arranged obliquely from the entrance, on which the access staircase to the first floor was once supported, a smaller enclosure is formed. The ground floor has a height regime of 3.80 m, and the first floor 2.20 m. The floors are on a solid wood structure made of large walnut beams; they are decommissioned and visible. The second floor has a rectangular part of which only the vertical wooden pillars remain, with access to the attic from the West facade. The attic has the trail of two massive chimneys, it has a frame of fire wood and perimeter (from the old structure) wood walnut, and the covering is galvanized sheet metal, damaged, torn off in some places, through which meteoric water enters the Pavilion premises.

4.1 Evolution over time

The Banloc ensemble has gone through numerous changes over time, and the Hunting Pavilion, in turn, presents several aspects of some changes. Following the study of the building in situ and vintage photography, some alterations to the original floor and frame were hypothesized.

The current state of the building provides several details that could be observed and analyzed, such as the frame structure with "A" rafters joined in wooden nails, the rest of the frame joined in metal nails, visible irregularities in the frame structure, unpaired elements, missing elements, tile slats and broken tile fragments, the existence in the structure of the wall on the first floor, of a perimeter belt of 2 wooden beams positioned one below the other, with a distance between them and connecting posts. On the facade, it was observed that the gable lowered below the level of the ceiling on the first floor and the roof cornice that lowers the register visible on the outside, below the current level of the ceiling, respectively up to the level of the beginning of the gable. Compared to the old photo (Fig. 3) in which this pavilion appears, today the building has undergone changes only at the level of the covering materiality. In the photo there are existing chimneys that are now fallen, with a high, slightly disproportionate height and two brick girders in their structure. The same roof shape as today is seen, but with a combination of tile and sheet metal cladding, currently only sheet metal.

Outside the building, below the level of the natural terrain, there are fragments of a concrete pavement and elements for collecting meteoric water, made of mosaic.

Initially, the Pavilion was the jewel of the Banloc ensemble. With a richly ornamented facade, it imposed itself despite its small size (Fig. 3). In present, due to multiple causes it has become a ruin (Fig. 4).

Fig. 3. Initial aspect of the Pavilion.

Fig. 4. Actual situation of the building.

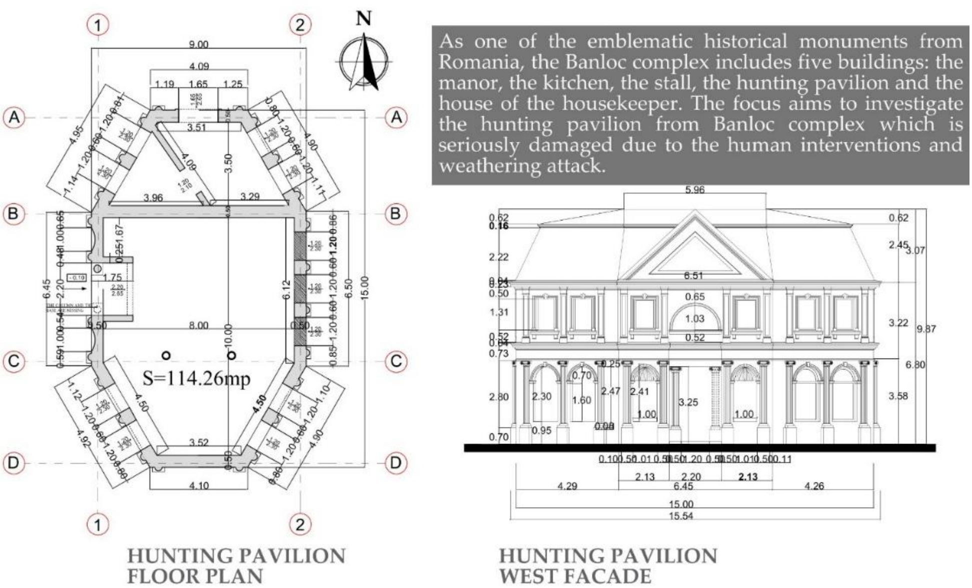

Fig. 5. Pavilion plan and west façade.

The Pavilion building has an elongated octagonal shape (Fig. 5) plan, with a masonry structure and a brick foundation; it runs vertically on two levels and has a wooden frame with sheet metal coverings. In approaching the solutions to consolidate the historical load-bearing structures, we have a coherent staged course of actions that must be carried out, respecting the order of implementation, namely:

1. Supports of load-bearing structures;
2. Consolidations of the historical building;
3. The restoration proposal based on the critical hypothesis issued within the project.

4.2 The restoration proposal morphed on the critical hypothesis issued within the project

The proposal for the conversion of the Hunting Pavilion building, provides for the preservation of the building's architectural integrity, as it is the only one with rich ornamentation on the outside and which is the jewel of the entire Banloc Complex. This is also the reason why it will be treated as a unique piece in the park, as a whole, both inside and outside. Considering the purpose of the building, that of a small concert hall with a maximum of 50 people, it will be empty on the inside (the wooden floor over the first level and the two interior walls will disappear), opening on two levels.

Considering the colours that were practiced and that were fashionable two centuries ago, the interior will be based on two basic colours: Chinese green and English red.

The carpentry will be Chinese green, it will have frames and windowsills on both the doors and windows, with double-layer, double-paned glass, shields and bronze hinges in the classic manner, but massive, not ordinary sizes. The floor, after the installation of the heating system in the floor, supplied with caloric power from the proposed semi-buried technical building at the intersection of the extreme northern lines between the Pavilion and the Superintendent's House, will have natural stone as its material, in a classic rectangular game of marble squares Botticino (or similar), bordered by a game of Guatemala Green marble (registers 8 cm wide) - the intersections between these registers will be made in 8x8 cm squares of Rosso Verona marble (that English Red) which can go up to Red emperor. The perimeter edge on which the pillars of the metal structure are located will be treated as a horizontal border also of Guatemala Green marble, 80 cm wide; due to the elongated octagon structure, all the internal pattern of the pavement will turn at 45 degrees, compared to the N-S axis (Fig. 6).

Fig. 6. Aspects of the Pavilion – Interior proposal.

Fig. 7. Outdoor proposal Hunting Pavilion.

The plinth will be of very high wood - 20 cm, grooved, colour identical to the carpentry; similarly on the wall at the height of 90 cm there will be a belt less wide than the plinth. A dramatic drapery system will be practiced from the height of the ceiling on the second level (painted matte black). They will be made of velvet in shades of warm petrol green. The lighting system will be done in a modern style, on two horizontal crossbars, mounted under the black ceiling, with rectangular reflectors, with dimmable light, with voltage variator, on LEDs, maximum power 4000K (each); they can also be fitted with RGB LEDs, with automatically interchangeable colour to the rhythm of the music (in fact, its frequency will change the light), which is made on a 5-wire system, with an interface taken over by a laptop.

The furniture will be the only one that will line up with the lighting fixtures, in a simple, modern style; the chairs will be made of transparent acrylic material, all black, only on the central row they will be red, giving strength to the whole environment.

The exterior will be uniformly chromatically treated, in a greige-white shade, which takes over from the inside the Chinese Green carpentry, with exterior glazing beads made of Guatemala Green marble (Fig. 7).

The newly created shell will be very dark gray-brown in colour. The external night lighting of the building will be of an architectural type, with wall-wash type lighting fixtures, which will mainly mark the adjacent pillars, washing them vertically in columns of light with sodium vapours (the light is slightly more yellowish), compared to the scoring of the entrances or the middle perimeter light, above the decorative profile, which will be much cooler, with a power of 6000K.

5 Failure mechanisms

In the following picture (Fig. 8) are the collapse mechanisms of the Hunting Pavilion; where in Fig. 8a. are the disposal, near the hollows of windows and doors, respectively near the buiandrugs.

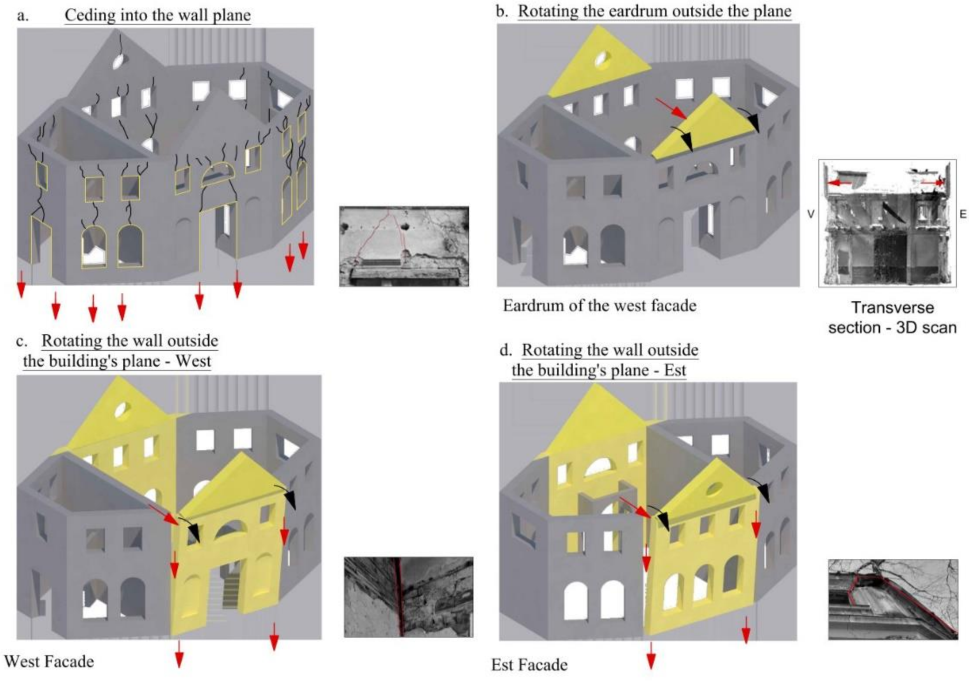

Fig. 8. Climb-down mechanisms: a. In-plane failure mechanism, b. Out-of-plane failure mechanism, c. Overturning West, d. Overturning East.

Resistance of low bending and presence at the north and floor entrance, of flattened discharge springs whose stability has decreased over time by destabilizing the support points.

Due to the high percentage of holes, the wall resistance has been reduced over time following the land and the weight of the entire construction.

In Fig. 8.b. - the turning of the eardrums of the building is present on both facades, west and east. Their rotation outside the plane is caused in particular by the weak connection of the eardrums with the walls and the roof and accentuated by the preying of the foundation. The western eardrum is visibly rotated outward than the eastern one.

In Fig. 8c. -the transfer by rotating the walls outside their plane, is especially present on the western and east walls of the building. The western wall is the most bent outward, with a rotation of about 5 cm compared to the vertical. These spins are caused by the push -inside pushing, horizontally on the walls and a destabilization at the foundation level. The walls are still supported by a good connection between the frame and they, respectively by the good weaving of the masonry on the corners.

In Fig. 8d. - on the east facade, also rotated outwards with about 4 cm, it is observed that there is a good connection between the inflexion areas of the walls, by the outside movement of the wall together with a portion of the south-eastern facade. The bricks are weaved correctly and helped to suffer the entire building over time.
All this is due to the uneven soil tasage.

5.1 Provision of work

At the Hunting Pavilion we will have mandatory masonry support. They will be rigid, so as not to deform, compressed, so as not to work in tension, and they will have to face contractions from humidity and temperature variations. A wooden structure was proposed, with different dimensions and on several layers, located outside the perimeter of the building, on all sides from ground level to under the envelope (Fig. 9) 3D.

Fig. 9. The exterior cladding of the building with a wooden structure and the perimeter reinforcement by tensioned cable, on four levels.

It will have several layers because the facades are richly ornamented and we have a vertical planimetric, many volumes that come out of the building plan; this wooden structure will be tied horizontally with tensioned cable, on four levels: three cables on the first level: one at the base, one at the middle of the height of the window openings; the third at the top of the ground floor; floor, having a very low height regime, the fourth cable is made in the middle of the height of the second level. The cables on the ground floor of the building that pass through the door openings will be interrupted, to facilitate access to the building, during the construction site.

Also, wooden structures will be built in the gaps of the windows and access doors, in order not to endanger the dismantling of parts of the building after the start of the consolidation works. All these structures will be temporary, and in the end, after the consolidations are done, they will be dismantled. Also at this stage, the floor supports must be made.

5.2 Consolidations

At this stage, the foundation will be consolidated, for which we present two options:

1. The first in which the sub-foundation is carried out, under the sole of the current foundation, in stages, in sections of 1.00 meters with a break between them also of 1.00 meters, with a depth of 0.60 m below the current level of the brick foundation (Fig. 10).
2. The second variant in which a lining is made to the inside and outside of the foundation, perimeter, starting with it 10 cm from the current ground level, downwards.

Fig. 10. Wooden reinforcements at window gaps and types of sub-foundation: a. under the base of the foundation.

Fig. 11. The metal structure from inside.

At the moment when the foundations are being consolidated, the foundation cups must also be executed for the metal structure proposed inside, which will be presented later. The concrete slab with appropriate thermal insulation will be poured over them, at a level 10 cm below the tread level.

Also at this stage, the interior plastering will be removed, because organic substances harmful to health were discovered following biological analyses, the cracks will be treated with injections, and then the missing masonry will be completed. Next, the floor will be consolidated above level 1 (this remains the only original one - from the current wooden structure).

At this moment, the interior metal structure (Fig. 11) can be mounted, which consists of pillars with a diameter of 250 millimetres, which take the form of the two pillars in the building, currently present, but which will be dismantled; the shape of the new pillars will be preserved in their memory. They will be located 40 cm towards the inside of the building (perimeter) and will be located at each change of direction of the walls. They will support at the top a perimeter structure of a rectangular, latticed pipe, 900 millimetres wide, which will reinforce the whole structure and which will be anchored in the walls, stopping the opening of the two with problems - the wall on the east facade and the wall on the facade from the west, which tend to open outwards. The building will remain empty inside, on the height of two levels, giving amplitude to the created volume, which reminds of the grandeur of the period in which it was conceived and built.

On the entire surface of the walls on the inside, the reinforced mesh with clips will be mounted, to strengthen the walls.

From this point, you can proceed to the opening of the frame, which will be completely replaced, it being of weak fir essence, in a very advanced state of decay and with many elements missing.

Then the external supports will be dismantled and the electrical installation inside and outside, as well as the heating and cooling, will be carried out; followed by interior and exterior plastering. The perimeter sidewalk of the building will be redone with the collection of rainwater in a buried system (below the level of the sidewalk). The next stage would be the restoration of all the ornaments and decorations on the facades and the double-glazed carpentry will be installed on laminated wood, with a frame and window sill on the inside.

6 Investigations

Several investigations were carried out on mortar samples taken in situ, from the building of the Hunting Pavilion.

Some analytical techniques, as: X-ray diffractometry (XRD), Wavelength Dispersive X-ray fluorescence (WDXRF), optical microscopy (OM), zoom microscopy, Infrared spectroscopy with Fourier Transformed (FTIR), have been used in order to clarify the main aspects about the structure, composition and morphological of the investigated samples. The oxides composition has been recorded by X-ray fluorescence (WDXRF) and the possible organic impurities has been identified by FTIR/Raman spectra. The morphology has been investigated by optical, zoom microscopy, which revealed the colors, fissures, cracks and even holes of these samples due to the time weathering processes, and damages they suffered in time. For the investigated samples, have been used the following equipment's:

- **X-ray diffraction (XRD**) with a Rigaku Ultima IV X-ray diffractometer (Rigaku, Tokyo, Japan), with the following parameters: wavelength of Cu-Kα radiation ($\lambda = 0.15406$ nm), 40 kV and 30 mA, angular range 5°–80° 2θ and a scan rate of 2° min^{-1}. The data processing has been obtained by the Rietveld (for identification of the components, cellular network, crystallinity, crystallite size).
- **Wavelength-dispersive X-ray fluorescence (WDXRF)** with a Rigaku ZSX Primus II spectrometer (Rigaku, Tokyo, Japan): 4.0 kW Rh Anode X-ray.
- **Fourier transform infrared spectroscopy (ATR-FTIR),** with a Vertex 80 spectrometer (Bruker Optik GMBH, Billerica, MA, USA), in the range 4000–400 cm−1 equipped with a DRIFT accessory.
- **Optical microscopy**: with a Novex trinocular microscope (Euromex Microscopen B.V., Arnhem, Holland) (magnifications: 40Å~, 100Å~, 400Å~, 1000Å~), equipped with a digital video camera (Axiocam 105, Zeiss, Göttingen, Germany)
- **Stereo trinocular stereomicroscope** (EUROMEX Microscopen B.V., BD Arnhem, Holland), with a magnification degree of 7–45Å~.

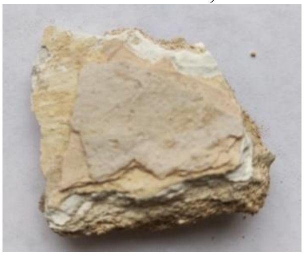

Fig. 12. 7 layers of the sample.

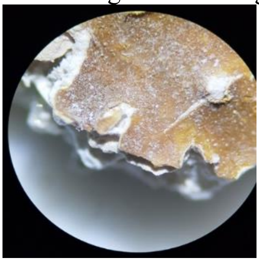

Fig. 13. Stereomicroscopy.

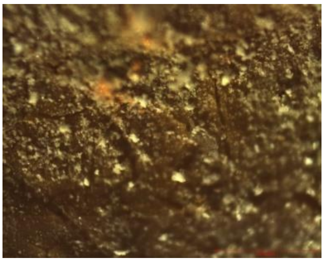

Fig. 14. Optical microscopy.

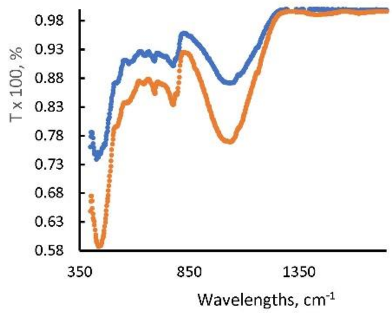

Fig. 15. FTIR Analyse of hunting pavilion sample (calcium carbonate ($CaCO_3$): 1409, 705 and 611 cm^{-1}, gypsum ($CaSO_4 \cdot 2H_2O$), 1109, 669 and 596 cm^{-1} and clays: 1032 cm^{-1} (Si–O–Si bond)).

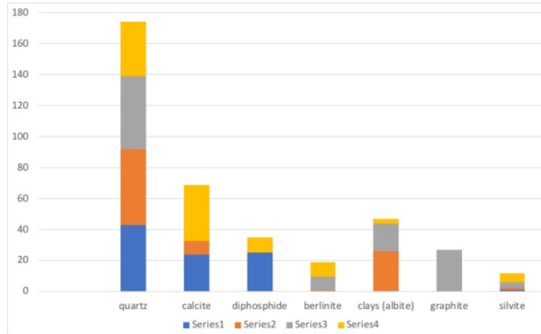

Fig. 16. X-ray diffraction.

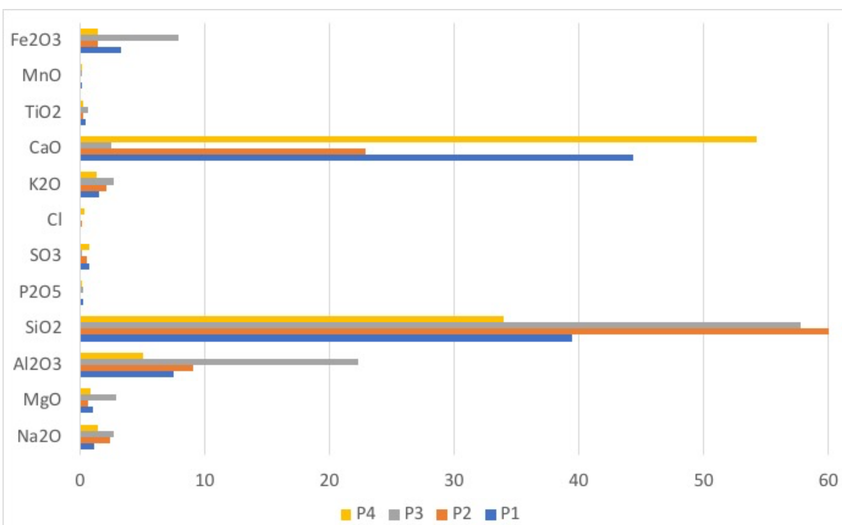

Fig. 17. X-ray fluorescence.

By visualization, several layers of mortars could be seen in different periods. About 7 layers of such layers were observed (Fig. 12), each having different color as proof of the level of degradation. These layers could be observed by stereomicroscopy, along with efflorescence layers (Fig. 13). By optical microscopy were observed: silica (white) or hematite (red) points present in the last mortar layer applied to the area subjected to investigation (Fig. 14).

Obviously, through FTIR (Fig. 15) it was possible to identify calcite (from lime), quartz (sand) and clay (albite) from the raw materials present in the area. From here it is possible to deduce that as restorations or consolidation procedures of the investigated area were made, the raw materials brought from other areas (at the first layers of mortar) were given up and raw materials from the Banloc area were used. FT-IR analysis proved the biggest band at around 1000 cm^{-1} representing the abundance of quartz, albite, calcite, berlinite in the studied materials.

A proof in this sense is the presence of the clay but also of the Berlinite - calcium phosphate (highlighted by the X -ray diffraction) (Fig. 16) but also by the presence of CaO and phosphate - identified by X -ray fluorescence (Fig. 17).

It should be mentioned that berlinite and generally phosphates have been mentioned in other tests in this area and reported by our group [17] and [18]. All these layers of mortar are in investigation at this time and the final results will be subjected to a final comparative analysis.

The identification of the mortar composition and the previous restorations that took place at this objective, plays a defining role in the choice of cleaning solutions for the wall surface (with massive efflorescence) as well as the materials that can be used for the reinforcements required at the level of this assembly [19].

7 Conclusions

As long as there is culture and respect for our history and implicitly leaning towards protecting and maintaining the tangible cultural heritage, we are a won people, who continue to transmit our identity as Romanians to our ancestors.

Tangible material heritage with its components - whatever the field from which the objects that compose it come from - is characterized, starting from the constitution of its component materials, by fragility and timeliness, but also by uniqueness and potential unity, which makes it irreplaceable. The researches of the last half century have detailed all these aspects determining the intensification of efforts for a scientific protection of the cultural heritage.

The topic of preventive conservation is only one facet of the effort to recover the belief in identity, and in operational terms it means maintaining the work of art carrying values in appropriate and constant conservation conditions by establishing a rigorous control system and minimal intervention measures.

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