Restoration and Preservation of Cultural Heritage Monuments

Digital Presentation and Practical Solutions

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Abstract. In the light of the recent concerns in the assessment of the new conservation treatments and of the development and application of methodologies, technologies, models and tools for CH damage assessment, this paper will deal with some innovative topics related to the digital models for protecting cultural heritage assets in front of various damages. Application of new technologies and digitalization of Basarabi monument is a preventive measure, helping us to build a virtual reconstructions as model for its potential reconstruction and preserving, to give access for the widest possible audience. It will be discussed the new technologies, as the non-destructive diagnosis technologies for the safe conservation a this historic, cultural and architectural – Basarabi churches. For the micro-climatic measurements, a number of sensors have been well distributed inside and outside and a diagram of humidity an temperature is evaluated. The practical examples of restoration and preservation and innovative solutions for the consolidation of this architectural monument, in relation with digitalization (by on-site and remotely data collection, virtual reality and documentation of the heritage). For a digital image of this monument, both a 3D laser scanner and some common digital photos are used, in order to obtain the 3D model of the church, and of the envelope of the church that should be applied over it to stop the seriously damage processes.

Keywords: cultural heritage; preservation; conservation; digitization.

1 INTRODUCTION

Romania is the owner of an impressive monumental and archaeological heritage in the context of global uniqueness of the Romanian achievements [1]. However, they require urgent measures that would reduce and, if possible, to stop the degradation process and hinder their final loss. One of the consequences of the monuments degradation is represented by the complex destructive factors (environmental conditions, biological factors, air pollution, the human factor itself, etc.) leading to the loss of material characteristics or binding under the structure [2]. These materials are elements of cohesion of the components of a historical monument, starting with the foundation, masonry, up to the artistic finesse components adorn the architectural surfaces, such as mural or decorative stucco. So, the conservation-restoration of these architectural monuments, along with its artistic components, primarily involves finding treatment solutions addressing both international principles in the field (compatibility, reversibility, aesthetic presentation adequate resistance ageing, and absence of side effects) and specific constituent materials of the monuments [3].

In this paper it will be discussed the chalk limestone monument from Dobrudja named Basarabi Churches Ensemble. This monument is dated IX-XI centuries, is located in a hill of chalk cliff into a Roman career style, with churches, galleries branched vaults, housing the tombs. The monument is located into a lithological generated hill, consisting of chalks and chalky marnes. The limestone is compact, with variable thickness from 42 m to 95 m, and below them there are marl and limestone. From mineralogical and chemical point of view, the stone is mono-mineral ($CaCO_3$). After the discovery 1957, the assembly elements were partially crushed and the rock has been repositioned in a structure of reinforced concrete and cement mortar. A protective building of concrete has been built for more than half of the site; the rest remained under provisional protection of wood and tar paper. These constructions have not assured proper microclimate, especially in the facing incised. The moisture, enviromental humidity and water external sources could cause a crushing of the chalk rock, and this stone suffers over time changing his composition and structure [4]. From technical-mechanical point of view, the chalk stone has the following characteristics: porosity: 0.5-13.5 %, degree of saturation: 0.3-0.994 %, bulk density, 1.9-2.8 kg/dm^3. Due to the low resistance to freeze-thaw, some monuments have been covered with cements structures or with a provisory roof [5]. Cracks were injected with fluid mortar of cement and sand and embroidered added color close mortar chalk. The building originally designed protection would take place along the cliff massif chalk, covering the entire cave and would be divided into seven sections that correspond to areas of the monument. In order to evaluate the micro-climatic measurements, a number of sensors have been well distributed inside and outside. All these parameters help to identify and stop the destroying or damaging process of this monument from cultural and historical national patrimony.

In this paper, a 3D model of the church has been obtained by using both a 3D laser scanner and 3D photogrammetry, and an envelope of the church that should be applied over it, has been proposed.

2 EXPERIMENTAL PART

2.1 INSTRUMENTATION

The *infrared spectra Fourier Transformed (FTIR)* spectra have been recorded directly on the sample with a Perkin Elmer Spectrum GX spectrometer, in the following conditions: range 4000 to 400 cm^{-1}, 32 scan, resolution 4 cm^{-1}, gain 1. A small quantity of matter (1 or 2 milligrams) was grounded, then mixed with KBr and placed in a DRIFT cell.

The Quanta 200 Scanning Electron Microscope (SEM) was used to produce enlarged images of a variety of specimens, achieving magnifications of over 100,000 x providing high resolution imaging in a digital format. This important and widely used analytical tool provided exceptional depth of field, with no samples preparation. The morphological structure of paper fibers can be investigated through the images collected by SEM and allows a direct observation of paper.

Optical microscopy has been recorded with a Primo Star microscop, which offers the possibility to investigate the samples in transmitted light at a magnification between 4X and 100X. The equipment has attached a digital video camera (Axiocam 105) which, by the microscope software allows real-time data acquisition. The obtained images could easily be converted from 2D format in 3D through iţs software for a better viewing.

Freeze-thaw method for chalk samples, for 20 cycles, which have been determined by repetitive operations (dried at 105±5°C until constant mass (M_1), for 1 hour; immersed into distillated water for 15 minutes, removed from water, wiped with a dampened cloth, drained and weighed (M_2), introduced are kept at -20°C for 3 hours, at a distances of 10-20 cm of each other, removed from the freezer and submerged in water, for thawing at 18°C for 2 hours; the thawed chalk samples are weighted after the last cycle (M_3). The measure of degraded chalk have been calculated with the formula: $\% \mu g = (M_2 - M_3/M_1) \times 100$, where: μg = freezing coefficient [6,7].

Petrography thin sections examination, has been performed with a Leitz polarizing microscope.

*Geophysical measurements have been recorded b*y geo-radar measurements type, with an electrometric method "electric survey vertical "(EVS) and a gravimetric method. It were achieved a total of about 150 EVS sites, with depths of investigation 30m to 150m, made at different equidistance, depending on the degree of detail set.

Digital 3D model of the outer surfaces of the church has been acquired through the photogrammetric processing of the images using a 3D Builder software package, with a photo camera NIKON D1X (6.3 Mpixel camera). A proper image in the 3D space and the final 3D model has been obtained with the horizontal and vertical measurements of distances between well-distinguished points on the 3D objects.

3 RESULTS AND DISCUSSION

3.1 Technical geology works

Basarabi archaeological site is located in a hill which from lithological point of view consist of chalks and chalky marl, Figure 2.

During the year, in Dobrudja four distinct seasons are registered: summers (early June and end in mid September) are warm, dry and sunny, autumns which start late September are long and relatively warm, with temperatures above 20°C during the nights. The first frost occurs on average on November. Winter is much warmer compared to other cities in southern Romania. Snow is not abundant but the weather can be very windy and thus, unpleasant. Winter arrives much later than in the interior and December weather is often mild with high temperatures reaching 12 °C. Average January temperature is +0.4 °C. Spring arrives early but it's quite cool. Often in April and May the Black Sea coast is one of the coolest places in Romania at an altitude lower than 500 m.

The average was 6.5 °C showing an exceptional 6 degrees departure above the normal. The last summers were the hottest in history with a record average temperature of 23.0 °C with 3.5 degrees above the normal range.

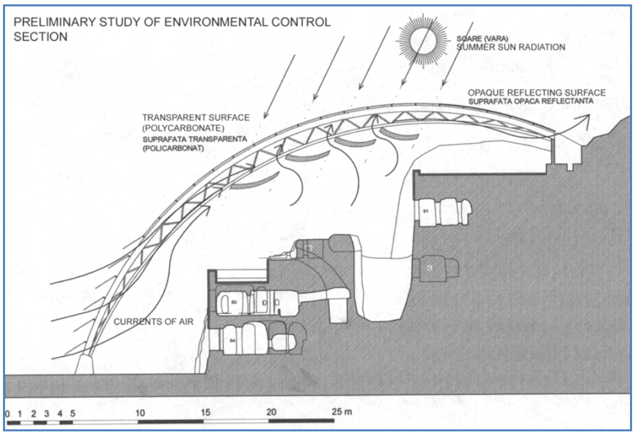

Fig. 1. The scheme of the polycarbonate enclosure [8].

Fig. 2. The photo of naos

Measuring the humidity in those 9 points from monuments interior, was possible to see a similar conclusion as previously reported [9]. As the deepest is the measurement points, the highest is the humidity. So, inside of the monument (naos) is a higher humidity and the degradation processes are stronger, Figure 3.

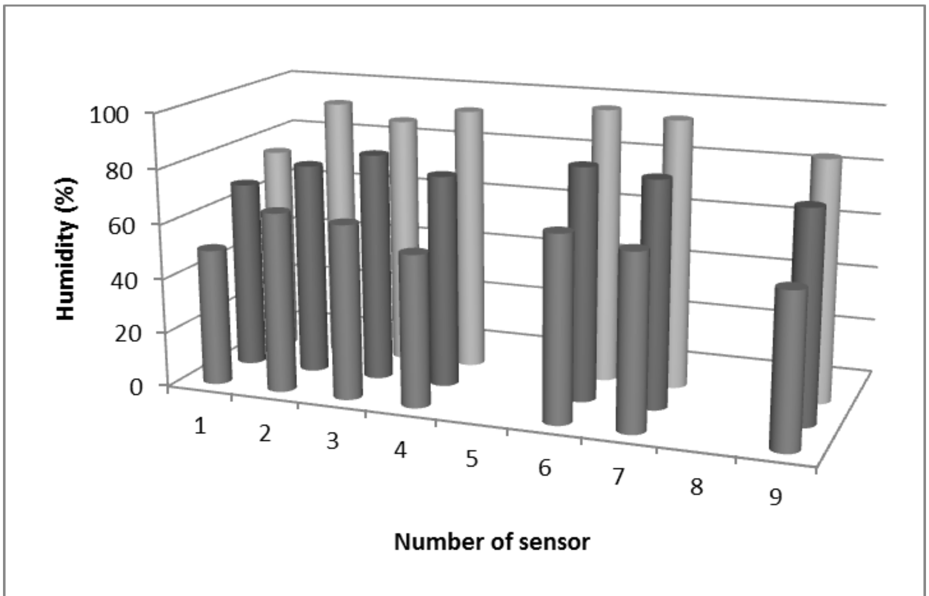

Fig. 3. The humidity variations for Basarabi church (in 9 points executed in naos)

The groundwater conditions hydro-geological site near the monument, water accumulation and possible leakage of leachate from rubbish to landfill career, have been achieved building six bore holes to depths of 15 to 20m, located outside the site and research role hydrogeology and geology. The determined degree of saturation, defined as the ratio between natural humidity (W_n) and the humidity of the same rock but saturated with water (W_{sat}), has the value of 0.3-0.994. From petrographical and mineralogical analysis, could be concluded that some varieties of calcite, as vaterite, which is very unstable (is stable only under 10 ^{O}C) and has the tendency to form framboidal structures, in the presence of CO_2 [10]. These framboidal structures are aggregations of smaller, mostly spherical, particles, with an average size of these elementary spheres comprised between 36 and 150 nm. It is very sensitive to water, too. If water can enter a rock through crevices, fractures or capillary spaces and subsequently freeze, the rock will be subjected to extremely high pressures which may cause shattering or cleaving if the rock is weak. The Chalk is considered highly susceptible to the actions of frost because has a high % void space within its structure allowing moisture to enter the rock and is a fine grained rock with multiple planes of weakness making it a relatively weak rock with low tensile strength and little resistance to frost action, Figure 4. In conjunction with these factors, the presence of salt within the moisture from the sea may facilitate the disintegration of rocks [11], by lowering the freezing point producing longer periods of thaw which would allow for longer periods of moisture adsorption. This test method does not provide an absolute value but rather an indication of the resistance to freezing and thawing; therefore, the results of this test method are not to be used as the sole basis for the determination of rock durability [12]. At the completion of 20 freeze-thaw cycles, the mass loss of the samples was determined to be significantly (7%).

Fig. 4. The aspects of the chalk wall dried (up) and wet with efflorescence (down)

The same results could be observed by FTIR analysis, Figure 5. B4 as a piece from a wetter side of the monument, shows a higher water concentration (1600 cm^{-1}) and with a high concentration of sulphate, due to efflorescence generated on this side (900 cm^{-1}). All these are missing or less signifiant for a dried surface (name here BMR).

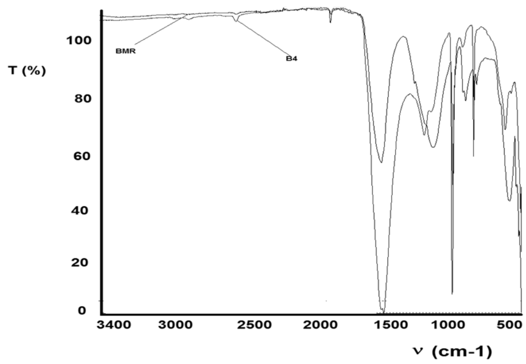

Fig. 5. FTIR spectra of dried (BMR) and wet chalk wall (B4)

Taking into accunt these experimental data, is obvious that water and temperature variations are the most aggresive factors affecting this monument, and should take some measures in order to save this important monument, and the virtual digitalization could be the first step in this context

Application of new technologies and digitalization of Basarabi monument is a preventive measure, helping us to build a virtual reconstructions as model for its potential reconstruction and preserving, to give access for the widest possible audience.

Laser scanning, 3D modelling, digital scanning and photogrammetry are the most used methods to digitize cultural heritage in order to provide 3D models. By means of Laser scanning technique, for this monument was possible to measure topographic quantities, the direction of a virtual optical line joining some points from the surface of the monument to a reference point on the measuring device and the morphological characteristics on th monument that can be acquired and measured with a very high accuracy [13]. It has been obtained a mathematical representation of a 3D surface, by means of CAD modelling to create the 3D model of the external projection of the church, Figure 6. As an alternative, the common digital photos can be used, to obtain 2D or 3D coordinates from some photos. The method can be aided by CAD software, which can produce good models for scales of 1:100 and higher [14-16]. In our case by using 3D photogrammetric has been obtained the 3D model of the envelope of the church that should be applied over the church, Figures 7 and 8. The created 3D model was 0.72-0.95% precise.

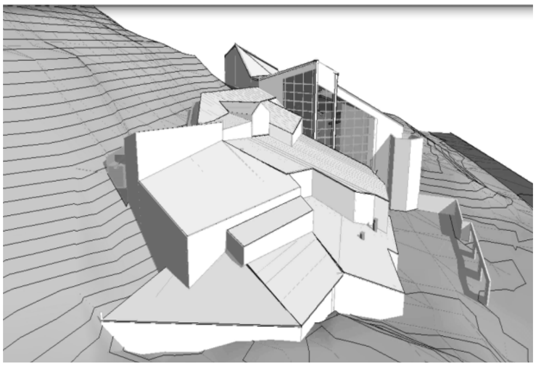

Fig. 6. The exterior digital projection of the monument

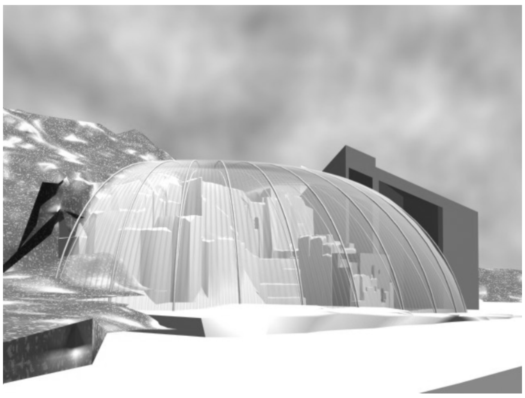

Fig. 7. The scheme of protection roof.

Fig. 8. The protection overlapping the church

4 CONCLUSIONS

The chalk limestone monument from Dobrudja - Basarabi Churches Ensemble, has been analyzed and digitized in this paper. From mineralogical and chemical point of view, the type of the the stone has been established, as is mono-mineral ($CaCO_3$). Due to the low resistance to freeze-thaw, is absolutely necessary that this monument to be covered with special structures or with a provisory roof which has to assure a proper microclimate. In order to evaluate the micro-climatic measurements, a number of sensors have been well distributed inside and outside and a diagram of humidity an temperature has been evaluated. All these parameters help to identify and stop the destroying or damaging process of this cultural and historical objective. For a digital image of this monuent, both a 3D laser scanner and some common digital photos can be used, in order to obtain the 3D model of the church, and of the envelope of the church that should be applied over it to stop the seriously damage processes.

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