European Journal of Science and Theology, June 2013, Vol.9, No.3, 139-148

NON DESTRUCTIVE EVALUATION OF LANTERN TOWER CHURCH OF DRAGOMIRNA

Ileana Kisilewicz*

'Spiru Haret' University, Faculty of Architecture, 13, Ion Ghica street, Bucharest, Romania

(Received 25 June 2012, revised 15 March 2013)

Abstract

The deterioration of the local Molid (lime) limestone from the Lantern tower of the Dragomirna Monastery's Church, compound erected in 1609 in the North-East Romania, determined a survey and preliminarily research for elaborating an intervention plan. The conservation works has been carried out till 2011. The decorated carve stone lantern tower of 'Holy Spirit' Church of Dragomira Monastery reaches 42 meters height and it is the tallest 17th century building in Romania. The presence of a consistent layer of dark lichens raised issues concerning biological treatments. The mapping of decay and then the lab tests revealed a wide variety of lichens on the stone surfaces. The research and investigation it have been sought for giving diagnosis of decay and to identify an adequate methodology treatment which it would be applied on stone surface. The paper, below, presents the final results obtained after the assessments of the carved stone conservation status which has been carried out in the framework of W.M.F. – Kress Foundation European Preservation Program.

Keywords: limestone, decay, mapping

1. Introduction

The carved stone decoration on the exterior lantern tower of the 'Holy Spirit' Church is an essential part of the cultural heritage of Dragomirna Monastery built in 1606-1609. The 'Holy Spirit' Church was erected by the metropolitan Atanasie Crimca helped by the Stroici family, a local noble family. In 1627 the ruler Miron Barnovschi erected the compound, the ensemble of the defensive surrounding walls [1]. The 400 years old carved stone decoration of lantern tower is of unique quality in its craftsman achievement and artistic historical relevance.

The purpose of this monitoring was the identification of significant decay forms and their main alteration phenomena, which affected the carved stone decorations on the exterior lantern tower facades. The results helped to define needs and main orientations for the stone conservation activities.

* E-mail: arhitectura@libero.it

The installation of a suitable scaffolding permitted direct access to the lantern tower. So, it could be carried out detailed examinations of the lantern tower facades and its carved stone surfaces. The report documented the stone decay forms, as they could be observed from June to October 2004 as drawings presented in Figure 1. It was given an interpretation of the active alteration processes and base on that, proposals were discussed for a conservation strategy.

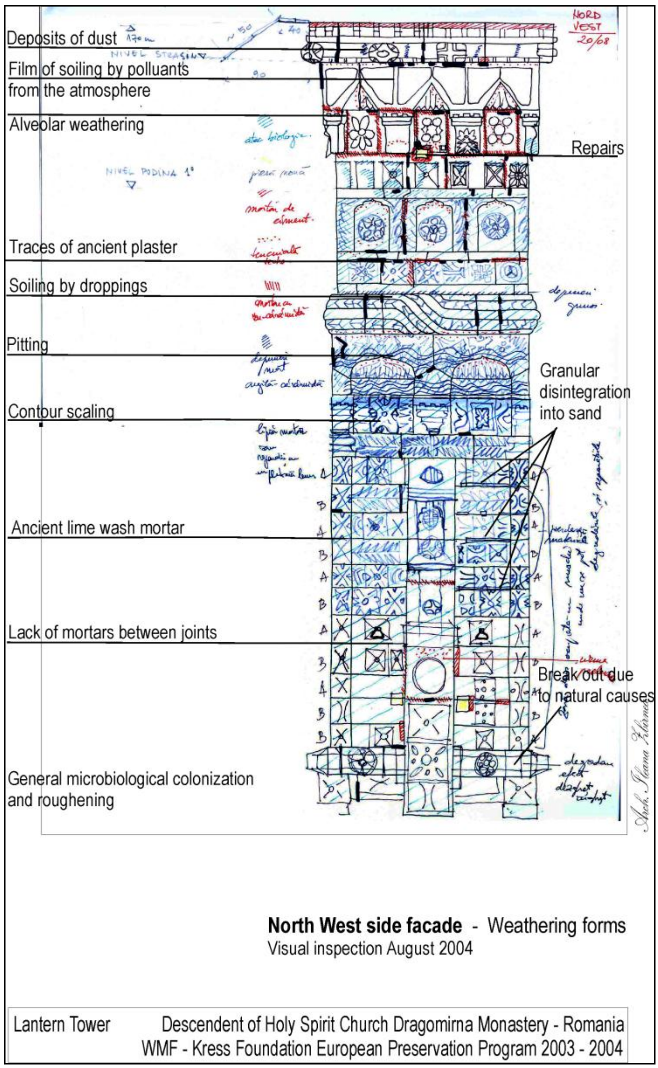

Figure 1. Scheme of pathology on N-W side of lantern tower.

2. Brief description of church and its conservation status

The lantern tower has an eclectic composition illustrating a large combination of different elements chosen with high freedom and fantasy, at that time. Rows of arcades shaped in triangle and in double accolades – with

Romanesque and Oriental features. The consoles may remember the Renaissance spirit. The prominent spin cord made by five threads, which connect all eight sides of the lantern tower, gives us more then the suggestion of continuity. The bishop Anastasie Crimca could have had a great influence in the lantern tower decorative design. It is well known that, the founder bishop of Dragomina Church was calligraphist and miniaturist during his young hood and several Holly books decorated by him proved his real gifted skill [2].

The original feature of the facades composition presents the option for non identical sides and thus each side has different decorated pieces of stone. Some unexpected stone motifs is used once as example: a hammer – on the N-W side, rows of rings – on the N side, the Greek cross – on the N-W side. The edges of sides were covered with similar plates of geometric flowers (tulips and roses) but, also, some of them were transformed in stars.

The dominant architectural element used at exterior and interior decoration of the church is the spin cord made by five threads. It lies horizontal once in the middle of the distance between the basement and the church roof and then it is upon the biphora motif of the lantern tower windows. On the contrary at the Cetatuia Church in Iasi city, this element is concentrated on the decoration of entrance [3].

Several works of conservation or some occasionally repairs were poorly described in the documents remained in the archives of the Institute of Historical Monuments in Bucharest. When some old buildings have been replaced by the new residence of the orthodox nuns – since 1960 till 1966 - it was done a complete file of works which, even, included descriptions of the works achieved on: the church, defensive walls, entrance tower, corner towers, the ancient ruler house-nowadays museum. The author of above mentioned project was the architect Ioana Grigorescu [4] one of the most remarkable Romanian restorer after WWII. Descriptions regarding the works on the lantern tower there were kept, in detail, in the economical documentation which makes part of that project.

Related to the church, the following works were described:

- the consolidation using a belt reinforced concrete on the top of the walls,
- the changing of the roof shape in order to put in light the carved stone decoration of the double ‘stellar’ base of the lantern tower,
- the cleaning up of the facades and of the lantern tower by ancient renderings using water and soap with washing soda,
- re-pointing the joints between stones using mortar with white cement, stone powder and colorants,
- removal of grey cement mortars between stones joints,
- repairs of damaged carved stone decoration using new stones by the same origin – the local stone quarry called ‘Piatra de Molid’.

3. Materials

3.1. Masonry and mortars

The outer facade of the octagonal lantern tower is composed of blocks of decorated stonework. These elements were laid with joints. Most of them there were fulfilled with mortar and often they were in good conditions without visible cracks. In some area it was noticed the lack of mortar joints. Also, rests of wood pieces could be found which it had been used to fulfil the joints during the initial building faze.

3.2. Plaster, renderings

Rests of yellow or brownish limewash renderings could be recognized on stone surfaces mainly on the upper parts of the tower, beneath the roof. They could be found on other weather-protected parts of the facade, too. This observation leads us to the presumption that, in the past, limewash renderings covered properly large parts of the carved stone decoration. As it is documented, stone surfaces were cleaned during the last restoration [Dragomirna Monastery (1960-1966), Archive of National Institute for Patrimony]. So rests of limewash rendering were removed. One can consider that the surface of the carved stone decoration has been directly exposed to weathering, at least since that time. The limewash layer had certainly an important protection effect for the stone surface and helped to diminish the impact of weathering.

3.3. Petrography of the stones

Almost all carved stone decoration on the exterior lantern tower is made of relatively dense oolitic limestone, rich in microfossil debris. The original stones showed a white to yellowish or a greyish colour. Two qualities could be distinguished: a more coarse grained homogenous limestone with visible calcareous debris of microfossils and a more fine grained limestone with bedding signs and greyish colours. The first variety is dominating and corresponds to the local stone quarry called ‘Piatra de Molid’. Both limestones have a relatively dense structure.

In spite of the high microfossil content, the porosity created by microfossil debris seemed to be advantageous for the durability of the limestone, which showed very little alteration problems due to capillary water suction. Large, partly isolated pores of the microfossil debris diminish capillary water uptake and prevent the stone from frost problems. On the other hand, the calcareous debris are soft mineral particles. This is a useful characteristic for carving ornaments or decorations on the stone surface. Only small quantity (less < 0.5%) of façade stones are clay rich sandstones used during former restorations as simple replacing stones. These stones are more susceptible to weathering and are not representatives for the carved stone decoration.

4. Survey and visible weathering forms

The visual inspection focused on the level of decay put in evidence inscriptions, on different sides and levels of the lantern tower, which could be craftsmen's signs.

Visual inspection, also, pointed out several weathering forms kept on eight drawings and photographic surveys. The stone surface was visually systematically studied. In addition, the stones were touched and tapped very carefully in order to recognize stone detachments, even those which were not visible. The individual weathering forms were recorded on individual drawings and large photos. There were noticed weathering forms developed individually or one above the other as in case of microbiological colonization developed on top of roughening surfaces or on surfaces with detachment on contour scaling. The survey results are inscribed in Table 1, following the Rolf Snethlages' [5] and classification of damages categories for the carved stone decoration are presented in Table 2.

The atmospheric conditions, in October, were completely different (rain, humidity, wind and temperature 5-10°C, during the day) than the campaign performed in August (sunshine, medium humidity, wind and temperature 20-25°C, during the day). After the completion of photographic survey for all eight sides it was possible to elaborate the quantitative and qualitative evaluation of frequency, extension and distribution of weathering forms.

The limestone surface was generally quite hard and did not give the impression having suffered from physical alterations but either chemical activities (acid rain) but a former activity of microorganisms had caused the important lost of mineral substance near the surface.

5. Main pathology and causes of decay

5.1. Loss of material from stone surface

The decorated stonework at the tower presented no significant signs of alteration caused by the direct impact of water, such as frost damage, swelling of stones or formation and disintegration of thin crusts.

The upper parts presented an important erosion and roughness on the stones surface caused by a loss of mineral substance. The relief of the stone decoration was diminished and sedimentary orientations of the limestone (bedding) has become visible.

Roughness could be recognize on the surface of several limestone blocks and mortar joints on the façade showing a so-called 'honeycomb' structure which is characterized by small round wholes or pits of about 1–2 mm diameter, a greyish colour and a relatively increased hardness. Their dimensions correspond with the size of small agglomerations of microorganisms present in the biomats. Thus, one could conclude that, the honeycomb-structure is in relation with the biological colonization.

Table 1. Weathering forms using Rolf Snethlage's classification of damage category.

WEATERING FORMS		**SIDES OF LANTERN TOWER**							
		SE	**S**	**SW**	**W**	**NW**	**N**	**NE**	**E**
Loss of stone material	• Clearing out of stone components				*				
	• Roughening	*	*	*	*	*	*	*	*
	• Break out due to natural causes				*	*	*		
Deposits – soiling	• Film of soiling by pollutants from the atmosphere	*	*	*	*	*	*	*	*
	• Soiling by droppings					*	*	*	
	• Dust	*		*		*	*	*	*
Deposits biological colonization	• Microbiological colonization	*	*	*	*	*	*	*	*
Loss of material – morphological change of the stone surface	• Alveolar weathering				*	*			
	• Pitting				*	*	*		
Detachment – granular disintegration	• Granular disintegration into sand					*			
Detachment	• Contour scaling				*	*			
Fissure				*			*	*	*

Table 2. Weathering forms, damage degree classification: X - very slight damage, XX - slight damage, XXX - moderate damage, XXXX - severe damage, XXXXX - very severe damage.

Loss of stone material - relief		
1	Clearing out of stone components – the matrix of the stone was washed out in a certain depth and the sediments become visible.	X - - - - -
2	Roughening – fine alteration of polished surfaces.	X - - - -
3	Break out due to natural causes – frost and thaw may cause explosion in the surfaces once the quantity of water absorbed is high in the moment of freeze.	- - X - -
Deposits		
1	Film of soiling by pollutants from the atmosphere – poorly adhesive mainly grey.	X X X - -
2	Soiling by droppings from birds.	X X X - -
3	Deposits of dust – mud and vegetal material.	X - - - -
Microbiological colonization		X X X - -
Loss of stone material – morphological change of stone surface		
1	Alveolar weathering – small cavities comparable to honeycombs.	X - - -
2	Pitting – small pitts specific to sedimentary rocks.	X X X - -
Detachment		
1	Granular disintegration into sand – detachment of smaller grains.	X X X X –
2	Contour scaling	X X X -
Fissure - small cracks on surface		X X X - -

Large areas of carved stone decorations, especially oriented on the S and E, there were found in a very good condition, almost without signs of weathering or surface alterations. The surface of these stone decorations showed, even, the original limestone surface without roughness caused by alteration or material lost.

Another effect, on the stone surface, it was the formation of small wholes or pits as described for the ‘honeycomb’ structures.

Figure 2. Soiling by droppings from birds and biological colonization.

Figure 3. Deposits of dust – mud and vegetal material and film of soiling.

Figure 4. Detachment on contour scaling and deposits of biological colonization

5.2. Deposits of biological colonization - distribution and intensity of growth

The limestone was not suffering directly from physical weathering. Nevertheless, the stones showed alterations caused by an important biological colonization. The carved stone decorations were covered frequently by ‘biomats’. These are association of microorganisms, which are covering the stone surfaces like a skin. They could be found in different intensities on the stonework around the tower. They were visible especially in lower parts of spin cord motif. The upper parts of lantern tower sides were often less affected by the growth of biomats properly (Figures 2 and 3).

An intense biological colonization there was discovered to be dominant on the façade sides oriented NW, N and NE. With exception of a small surface protected by the roof, the colonization took place along the whole vertical area of these façade sides. This exposition of sides is characterized by predominant wind direction with higher precipitations of meteor water (rain, main weather direction of the valley) and a longer presence of humidity due to the caused by absence of direct sunshine or condensation of water. These microclimatic conditions enhanced the presence of humidity on the stone surface and they favoured, base on the main weather direction, the growth of microorganisms like algae, fungi or bacteria.

Often, the stone relief was still visible, but covered by a layer of biomats up to about 1 mm thickness. The original white-yellowish colour of the limestone changed its surface into gray, black or green or yellowish depending of the nature of different microorganisms but the colour intensity depended of their growth stage.

Especially, an alternation of different species could be observed on the surfaces with intense biological colonization. The biomats appeared not as a homogeneous layer, but as centres of growth or colonies, which were expanded.

From colonized limestone and mortar surfaces samples were taken for studying the depth and the nature of the biomats. A determination of biological species was possible by comparison of microscopic views. Two species of lichens, there were identified on mortar and limestone samples, named: *Calcoplaca, Candellariela, Xanthoria elegans* and *Lecanora dispersa* [6].

On top of the limestone surface, biomats could be seen as a fine black layer covered by yellowish agglomerations of microorganisms. Underneath the limestone appeared in white fresh colour with debris of microfossils. So, the biomats formed only a very small dark layer, less than 1 mm thick. Similar observations could be noticed on mortar samples covered by bio-mats.

The presence of biological colonization changed the water uptake of the limestone: biomats acted as a supplementary layer which influenced the water exchange on the surface of the stone.

Properly the growth of microorganisms by the intake and release of water could caused an increase or decrease of cells, thus it results a mechanical stress causing local disintegration or dissolution of mineral material on the limestone surface. In this way, the whole remains were formed by the former biological mineralization.

6. Causes of decay

Evaluation revealed the largest pathology occurred on W, N-W and N sides of lantern tower then it decreased slightly towards S side. As the mineralogical report demonstrated that the N-W dominant wind direction and the absence of direct sun light plus the high humidity plus the low temperatures influenced the increase decay of stone surfaces of these sides.

On the surfaces with original carved stone occurred all categories of decay: biological, chemical and physical but in different percentages. The biological decay represented by the microbiological colonization was permanent and very active and had large extension on the above mentioned sides. The chemical decay, caused by natural reactions of stone under the rain either to aggressive cleaning made in the 60's, was slowly and had limited extension. The identified physical decay did not affect the general stability of lantern tower. This decay was represented by few small fissures which could appear during the erection of lantern tower (Figure 4). The window stone frames were broken around the bronze rings by which there were fixed the sashes, in previous time.

The quality of air was another factor influencing the growth of lichens: Thus, concentrations of sulphuric compounds hindering growth of algae decreased (decades of long pollution) in contrast to an actual increasing of concentrations of nitrous compounds (NOx), which are suspicious to cause eutrophication. This seems to augment the algae-problem actually.

It is also known that lichens growth results in water-retention on the stone surface. Therefore, biomats change the water regime of facades, which may lead to high water loads, offering good conditions for a further development of the microbial layer. Both, long-term moisture and corrosive excretions of biomats members augment biogenous as well as abiotic ageing processes on the stone surface.

7. General recommendation to conservation:

As it was noticed, the removal of ancient plaster, during '60 interventions, created a large surface that it suffered the roughening phenomenon. This fact increased the speed of adherence of all kind of materials transported by rain, wind and birds. It is also the fact that the air contains always a biogenious load from some hundred up to 1 million fungal spores per square meter and, additionally, algae and bacteria cells. They are ubiquitous and thus the stone surface could not be sterile.

Further considerations were made. The presence of lichens and the growth of biomats did not cause only an aesthetic problem on the surface of the carved stone decorations. There was a demineralization and a transformation of the upper limestone surface and, by the time, the stone surfaces submitted important changes. The original stone surface was changed. Continuing of biomats growth it would occurred further material lost on the surface of the limestone. Even, when the growth of biomats was slow down, for a period, due to unfavourable living conditions, microorganisms could contaminate the stone surface. They are resistant and continue to growth with the amelioration of their living conditions.

For the conservation of the original surface it seemed, not only for esthetical reasons, useful to remove the biological layer (biomats). In order to minimize the re-growth of microorganisms, especially lichens, it was proposed to treat, after a mechanical brushing the stone surface, with an H_2O_2 solution, which should to oxidize the remaining organic matter. Thus, the 'disinfected' stone surface could slow down the growth of microorganisms and could diminish the problem for at least 20 years. Otherwise an acceleration of biological colonization and an increase of deterioration of the limestone surface should to be feared.

8. The forecasted necessary steps of conservation and protection

The treatments recommended were: pre-consolidation of surfaces in danger to loose material, control of microbiological colonization, cleaning of surfaces starting from top, removal of old fillings of cement mortars, consolidation of stone surfaces, application of shelter coating. Before starting treatments will be chosen the appropriated and less dangerous products. All products must be tested before on small surfaces chosen by the architect.

Acknowledgement

The project was performed within the framework of World Monuments Fund and Kress Foundation European Preservation Program in 2003 - 2004, by an international team coordinated by architect Ileana Zbirnea (Kisilewicz)

Thanks are due to team: architect Dan Kisilewicz, Professor Oliviu Boldura, Grazia Fumo, Dino Chinellato and Professor Andreas Queisser, who proved excellent collaboration during the organization of the working program, and the development of the survey on the site. They shared gladly scientific information and useful opinions that enhanced the quality of the final assessment and the intervention plan. Based on these, since 2008 a group of restorers guided by Professor Boldura has worked till 2011 on the conservation of the stone surfaces of the lantern tower Dragomirna Church, in frame of a programme financed by Romanian Ministry of Culture.

References

[1] G. Ionescu, *Istoria arhitecturii in Romania II. De la sfarsitul veacului al XVI-lea pana la inceputul celui de-al cincilea deceniu al veacului al XX-lea*, Academia Republicii Socialiste Romania, Bucuresti, 1965.

[2] R. Florescu and I Miclea, *Dragomirna*, Meridiane, Bucuresti, 1976.

[3] M.M. Popescu, *Sculptura medievala in piatra din tarile Romane*, Merdiane, Bucuresti, 1985, 11, 41-42.

[4] V.D. Kisilewicz, Conservation of Architectural Patrimony in North-East Part of Romania. The Role of Architect Ioana Grigorescu, Doctoral Thesis, 'Valahia' University, Faculty of History, Targoviste, 2010.

[5] R. Snethlage, *Natursteinkonservierung in der Denkmalpflege*, Verlag Ernst & Sohn Grugh, Berlin, 1995, 41-88.

[6] G. Caneva, M.P. Nugari and O. Salvadori, *La biologia per i beni culturali*, Vol. I, *Biodeterioramento e conservazione*, Nardini Editore, Firenze, 2005, 55-80.