BABEȘ-BOLYAI UNIVERSITY CLUJ-NAPOCA
FACULTATY OF GEOGRAPHY

The role of weathering processes in the deterioration of stone-built and wooden monuments in Transylvania

SUMMARY

Scientific coordinator:
Prof.univ.dr. IOAN-AUREL IRIMUȘ

PhD. Student:
MONICA ILIEȘ

CLUJ-NAPOCA

2015

Table of contents

Key words: weathering, monuments, stone, wood, decay, tendencies

Introduction

The preservation of the Transylvanian monuments is inevitably endangered by the physical, chemical and biological weathering processes. The naturally occurring weathering processes, coupled with human neglect, can lead to alarming damage.

The objective of this research project is to provide an accurate damage diagnosis by correctly identifying both the causes (damaging processes), and their effects on historical materials (decay forms). Damage diagnosis can facilitate implementing certain conservation-restoration treatments that will preserve the monument's structural and aesthetic integrity.

The processes that damage both stone built components (physical weathering, chemical weathering and biological weathering) and wooden components (weathering and decay) were identified on six Transylvanian rural monuments: "Holy Archangels Michael and Gabriel", Turdaș Village, Alba County, "Birth of Saint John The Baptist", Gârda de Sus Village, Alba County, "Holy Archangels Michael and Gabriel", Runcu Salvei Village, Bistrița-Năsăud County, "Holy Archangels Michael and Gabriel", Ciumărna Village, Sălaj County, "Holy Archangels Michael and Gabriel", Poarta Sălajului Village, Sălaj County and "Holy Archangels Michael and Gabriel", Deag Village, Mureș County.

The "Saint Michael and Gabriel Archangels" Church in Deag Village, Mureș County was subjected to a complex damage diagnosis. This consisted of both in situ and laboratory investigations. The climatic conditions of the area were analysed, in order to determine which weathering processes are most likely to affect the monument. Also, special attention was paid to the diurnal temperature variations which cause freeze-thaw weathering.

Freeze-thaw weathering poses a great threat to the preservation of the lithic component. Its variability and tendencies in the Transylvanian Depression were analysed in the last chapter of the thesis.

1. WEATHERING OF THE STONE-BUILT COMPONENTS

The weathering processes are controlled by a series of extrinsic and intrinsic factors that determine their type and intensity. Intrinsic factors consist of the chemical, physical and mechanical properties of the stones. Extrinsic factors include: climatic conditions,

water, vegetation, exposure of the stones to the cardinal points, location of the stones within the monument structure and the anthropic action and/or neglect.

The most frequent forms of stone deterioration were identified on the six monuments mentioned above, by using the classifications and specifications developed by Fitzner and Heinrichs (2002) and ICOMOS-ISCS (2008). The decay forms identified in situ belong to the five main groups: loss of stone material, discoloration/deposits, detachment, fissures/deformation and biological colonisation.

2. WEATHERING AND DECAY OF WOODEN COMPONENTS

According to LeBow and Anthony (2012) wood can be affected by weathering processes and decay. Weathering affects the surface of the wood and is caused by physical, chemical and biological processes. The two authors consider weathering to be the first stage of wood deterioration. It is caused by UV radiation, humidity and temperature variations. Williams (2005) considers mould and wood-staining fungi as weathering agents.

Decay is brought on by fungi, insects, lichens and moss. These organisms can penetrate deep inside the wood causing severe damage. Infected wood can be completely destroyed in a very short period of time if humidity and temperature are high enough.

The weathering related deteriorations and decay forms were identified on the six selected movements.

3. METHODOLOGY

This chapter highlights the stages of the damage diagnosis that was applied to the "Holy Archangels Michael and Gabriel" monument in the Deag village, which is the subject of this case study. It shows the different types of decay produced by both weathering and biological processes.

Anamnesis

The anamnesis, realized in according with Fitzners model (2002), contains data used to identify the monument, its location, historical and artistic background as well as a summary of the repair and restoration works that have been applied to it. We also look at the different damages the monument has suffered over time and the climatic particularities of the area.

A specific aspect of the climate which the paper focuses on, is the damage caused by the diurnal temperature variations which cause freeze-thaw weathering. The aggressiveness of the diurnal cycles was determined by taking the following parameters into account: frequency, intensity, the number periods within a year with consecutive diurnal cycles and the maximum duration of these periods.

The trends of the freeze-thaw weathering parameters have been computed using a combination between the Mann-Kendall method and the Sen slope.

The maximum and minimum temperature values were obtained from the Tarnaveni (Bobohalma) Weather Station for a period of 27 years, between 1987 and 2014.

Damage diagnosis of the stone built component

The damage diagnosis process took place on site as well as in the laboratory. The in situ investigations focused on identifying the lithological type and the specific stone degradations. For a comparative analysis samples were lifted from the decayed rocks within the monument base, as well as from healthy rocks found in the source area. The different types of decay were mapped following their severity and distribution patterns.

Laboratory investigations of the rock samples revealed new informations regarding the causes of the decay forms observed at a macroscopic level. Decay forms that set on after the rocks were built into the monument are highlighted by comparing the two types of rock samples. Lab investigations include optical microscopy, SEM-EDX analysis and X-ray diffraction.

Damage diagnosis of the wooden elements

In situ investigation included identifying the various decay forms, mapping them and sampling severely decayed areas that show specific signs of biological colonization. The wood samples were then analysed using electronic microscopy (SEM) in order to confirm the presence of biological organisms.

4. CASE STUDY. "HOLY ARCHANGELS MICHAEL AND GABRIEL" CHURCH, DEAG VILLAGE, MUREȘ COUNTY

Anamnesis

The wooden church "Holy Archangels Michael and Gabriel" can be found on the historical monuments under the code M-II-m-A-15653. Deag Village is located in the central part of the Transylvanian Plateau, in the Târnave Hills, 8 km away from its administrative town, Iernut. The church was built in 1660 on Dealul Mănăstirii but was relocated in its current location in 1764-1765 (Cristache Panait, 1993).

The church has a two levels detached bell tower. The walls were constructed with pine wooden beams arranged according to the blockbau syste while the foundation was built with irregular blocks of sandstone, extracted from the nearby hills.

In 2011 the foundation was damaged due to some superficial landslides. Consolidation works have been employed to strengthen the southern and eastern part of the foundation. The original, eighteenth century, stone was replaced by concrete slabs, an inadequate choice from an aesthetic and structural point of view.

The chemical and biological weathering are sustained by an average relative humidity of 76%-80% and by the high temperatures recorded in the summer season. Frost weathering (freeze – thaw) is justified by the negative temperatures recorded during winter, especially in January when the average temperature is -4˚C, and also by the sudden temperature fluctuations between positive and negative values recorded in the transition seasons. The mechanical weathering through wetting and drying can occur during the warm season, when summer rains are fallowed by periods of intense evaporation. The wetting and drying process can be accompanied by the salt crystallization process, due to the rather low humidity recorded in the area.

The Mann-Kendall test and the Sen slope have determined falling tendencies for all the parameters. The frequency of the diurnal freeze-thaw cycles and the third group of intensity have registered statistically significant tendencies.

Damage diagnosis of the stone built component

The macroscopic analysis and the acid chloride test, revealed that the lithic material is carbonate cemented sandstone.

Macroscopic inspection revealed several weathering related decay forms: exfoliations along the bedding planes, granular disintegration, light-coloured crusts, coloured crusts, coloration (chromatic alteration) of the surface and biological colonisation. The decay forms were identified on all four sides of the base but they are more frequent and severe on the northern and southern sides. The decay forms were mapped following their severity and distribution.

The samples were collected from the northern and southern sides, from severely deteriorated stones that allowed easy detachment of the lithic material. Fresh rock samples were also collected from the source area, Dealul Chinciușului.

The samples were subjected to a series of laboratory investigations which include: optical microscopy, polarised light microscopy, scanning electron microscopy fitted with an energy dispersive spectroscopy (SEM-EDX) and X-ray diffraction. The comparative analysis of the weathered and fresh samples allowed an accurate identification of the weathering products.

The *optical microscopy analysis* of the fresh and weathered rock samples revealed that the latter presents a much higher porosity, indicating that its formation is weathering-related. The newly formed intergranular pores are the result of the dissolution of the calcium carbonate cement. The sand particles are no longer held together, thus making the rock less resistant and prone to granular disintegration (Ilieș et al., 2015). The analysis of such samples revealed a process of case hardening due to ferrugination. Microscopic images revealed a compact, iron oxides and hydroxides outer layer and an inner more fragile, porous layer. The lack of porosity in the surface layer indicates that in addition to iron oxidation, precipitated calcium carbonate and possibly other secondary minerals, have also contributed to the case hardened crust by cementing the pores. Because crust formation implies the weakening of the surface beneath, the stone integrity is put at risk.

Polarised light microscopy revealed that the sandstone samples consist of quartz, mica, feldspar, and bioclast fragments, cemented together with calcium carbonate. Polarised light microscopy also determined that gypsum has formed inside the pores and might have also contributed to granular disintegration by displacing original particles, through the pressure exerted during the crystallisation process (Ilieș et al., 2015).

SEM-EDX analysis of light-coloured crust identified gypsum as one of the main components, alongside calcite.

The X-ray diffraction analysis was conducted on a sample of fresh rock and four weathered samples. The x-ray diffractograms revealed a similar composition for all the

samples. According to the analysis, the main components of the lithic materials are quartz, mica and clay minerals. The clay mineral chlorite is present in all samples. Its diffraction line is very small in the diffractograms of the fresh sample (DDC) and the samples collected from the southern side (DS3, DS7). The chlorite line of the samples collected from the northern side is very high (DN3, DN4). Thus, alteration is predominant on the northern, more humid side of the monument.

Damage diagnosis of the wooden elements

The southern façade was weathered by UV radiation and humidity and temperature variations. The wooden beams have a reddish brown colour, a rough surface and cracks. Water infiltrations through the deteriorated roof have sustained the development of mould and insect attack, on the upper wooden beams. The northern façade has been subjected to moisture-related deteriorations. The wooden beams are discoloured with mould and insect infestation, especially on the lowermost beam. It was also affected by humidity and temperature variations that resulted in cracks and fissures. The weathering forms were mapped following their severity and distribution.

Small samples were collected from the southern and northern facades, from deteriorated areas that showed signs of biological weathering and decay.

Electron microscopy analysis (SEM) confirmed the presence of fungal hyphae and spores on both saples.

5. ANALYSIS OF FREEZE-THAW WEATHERING IN THE TRANSYLVANIAN DEPRESSION

Freeze-thaw weathering is one of the most active processes that contributes to the disintegration of stone-built heritage. Knowing its severity and tendencies is most helpful in the implementation of adequate conservation and restoration treatments. This study did not focus on any particular monuments, but rather on offering a general view on the action patterns and tendencies of freeze-thaw weathering in the Transylvanian Depression. The diurnal highs and lows were obtained from weather stations in Cluj-Napoca, Sibiu, Târgu Mureș and Bistrița. The results obtained from the Târnăveni (Bobohalma) analysis were also added to this study.

Cluj-Napoca and Târnăveni (Bobohalma) weather stations are characterised by falling tendencies for all parameters. The frequency of diurnal freeze-thaw cycles even

show statistically significant tendencies. The tendencies at Târgu Mureș and Sibiu are heterogeneous and the only statistically significant tendencies are the falling ones, identified for the first intensity group. At Bistrița weather station the tendencies are mostly stationary.

Conclusions

The climatic conditions are most important when analysing weathering processes and their effects on monuments. The values of temperature, humidity and also the way they associate, "decide" the predominant types of weathering that occur. The monument has two different microclimates, the northern one and the southern one, that favour particular forms of deterioration. In situ investigations also revealed the influence of the biological factor. Rich vegetation in close proximity to a monument creates a humid microclimate that favours chemical and biological processes. Even though the monument "Holy Archangels Michael and Gabriel", Turdaș village, Alba County, is located in an area with humidity deficit, it was still subjected to fungal, lichen and moss colonisation.

The stone-built base of "Holy Archangels Michael and Gabriel" monument from Deag village was damaged most severely on the southern side, by the physical weathering processes. Exfoliation caused partial and total disintegration of some of the rocks. They must be replaced with new, healthy ones, extracted from the source area.

The weathering processes did not cause alarming damage to the wooden components of the monument. However, the insect infestation and the mould must be stopped by implementing conservation treatments.

The tendencies of the diurnal freeze-thaw parameters registered significant changes in Cluj –Napoca and Târnăveni-Bobohalma. Their falling tendencies suggest that freeze-thaw weathering is losing its disintegration power, thus ensuring the preservation of the materials for a longer period of time.

.