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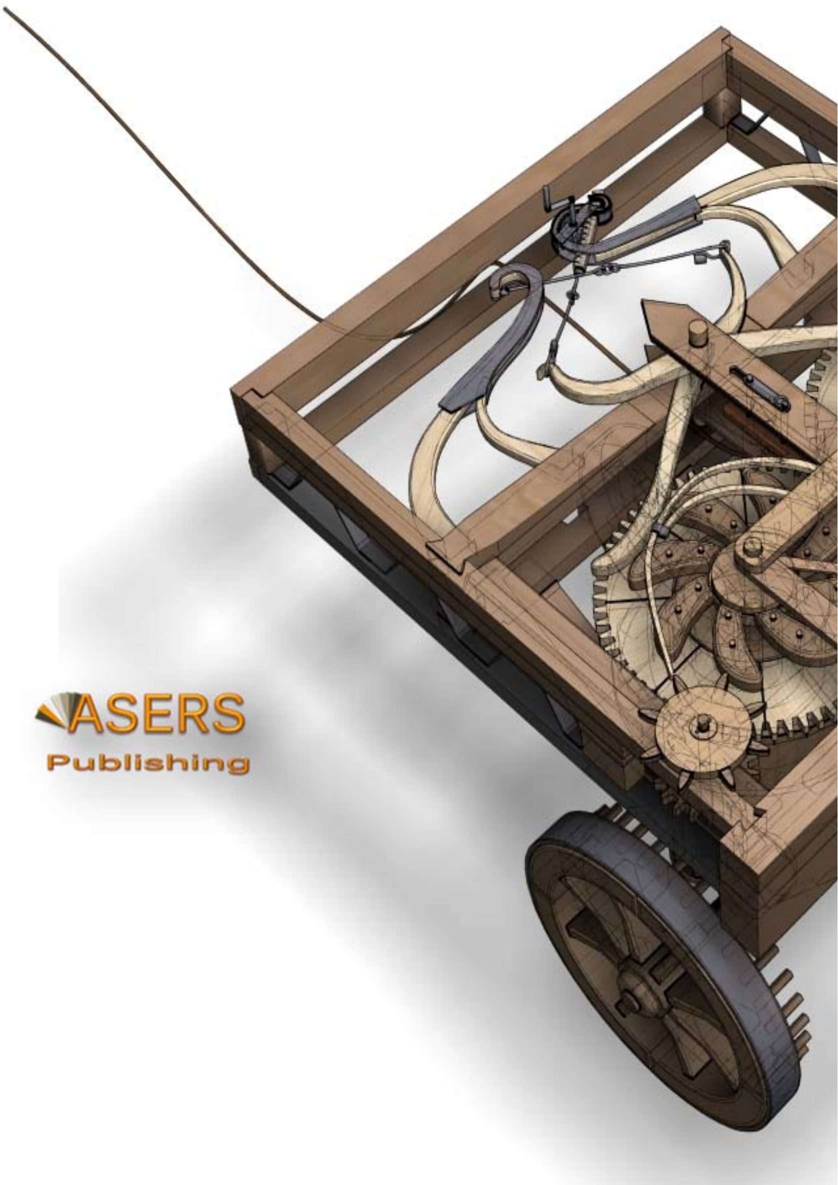

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The Needs for Determining Degradation Risks from Temperature and Relative Humidity of Post-Byzantine Church Indoor Environment

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Abstract:

Monitoring and dealing with particular conditions related to relative humidity (RH) and temperature within different cultural objects including post-byzantine churches are of primary importance for the current conservation and advancement. The objective of this paper is to explore and discuss how standards can be implemented and guide the decision processes in order to facilitate a sustainable management of cultural buildings. Following the particularities of the interface of Mediterranean and continental climate conditions, here is introduced a general climate risk assessment method, which determines how indoor climates fit into the selected post-byzantine cultural objects in Albania. A relative humidity over 75% and temperature frequently over 30°C within several churches is been assessed as a high risk of sudden or cumulative mechanical damage to most artefacts and paintings because of high humidity. Predicting preservation is an important aspect in preventing damage to objects. This paper also describes the historical and scientific background to the current discussions.

Keywords: indoor climate control; humidity; standards; post-byzantine; temperature; environmental conditions.

JEL Classification: Q51; Q53.

Introduction

The cultural heritage of a transitional economy like Albania is the most important assess for the tourism development. The key issue addressed in this paper is how scientific knowledge and best practices regarding indoor climate control should be shared to end-users in order to facilitate a sustainable management of cultural heritage. The use and conservation approaches, techniques of management of the buildings (particularly those medieval time), as well as assessment environmental impact related to indoor environment are highly influencing on their perspective. Ones the sharing of scientific knowledge and best practices for the indoor museums and their collection has advanced, the standards for indoor climate of cultural monuments of historical character are poorly understood.

1. Research Background

Ones in comes to museums and galleries, in the last three decades there have been invested in infrastructure and followed a policy of close control of environmental conditions in order to minimize damage to the objects that they hold. Following Thomson (1986) and Atkinson (2014), the issue of control is based on the behaviour of different materials, as far as this was known, and the values for relative humidity (RH) and temperature suggested were appropriate for the different climate conditions. In particular regions, where the Mediterranean and continental climate conditions are subject of influence, and cultural objects do not pose a controlled close environment the issue of indoor management is becoming a very challenging one. The core issue addressed in this contribution is how scientific data and good practices regarding indoor climate control in cultural monuments and other buildings of historical importance should be transferred to central and local mangers in order to enhance the proper management and conservation. Following Leijonhufvud & Broström, (2018) the use and preservation of the building and the collection, as well as the financial cost and environmental impact related to energy use are all dependent on the extent of indoor climate control. The determination of an indoor climate control practice comprises a very complex task, involving social as well as technical dimensions: conflicting objectives have to be negotiated, facets of management that commonly are separated have to be involved and different types of expertise is needed (Leijonhufvud *et al.* 2013; Leijonhufvud and Henning 2014; Leijonhufvud and Broström 2018; Camuffo 2014; Brown and Rose 1996).

Based on current practices it seems that the way scientific knowledge is utilized in these processes is poorly understood and further to current poor management in many extends the deterioration processes are smoothly progressing. Further on the climate around an object situated in the interior environment, *i.e.* indoor climate or a microclimate – may cause the object to deteriorate over time. Object deterioration is usually divided into biological, chemical and mechanical degradation. According to different references (Mecklenburg 1991) much of the damage found in cultural and artistic objects results from mechanical responses to stimuli such as changes in temperature, relative humidity, impact and vibration. Due particularity of cultural objects, the materials are organic, and their mechanical properties are dramatically altered by environmental factors such as changes in temperature and relative humidity (Mecklenburg 1991).

Table 1. Effects of relative humidity and temperature oscillations (0-1: very low impact; 1-2: low; 2-3: average; 3-4: high and 4-5: very high)

Name of the cultural object	Coordinate	Effects of relative humidity and temperature oscillations					
		Plaster	Paintings	Wood material	Wood material deformation	Stone material	Brick material
Monastery of Dormition of Theotokos Mary, Narta	40°51'38" N 19°39'45" E	3-4	3-4	2-3	1-2	2-3	3-4
St. Mary in Bishqethem	40°51'38" N 19°39'45" E	4-5	4-5	4-5	4-5	1-2	2-3
St. Thanasios in Karavasta	40°87'89" N 19°47'74" E	2-3	2-3	1-2	3-4	1-2	3-4
St. Nicola Church in Shelcan	41°30'40" N 20°80'30" E	1-2	1-2	1-2	2-3	1-2	2-3
Ardenica Monastery	40°81'87" N 19°59'26" E	1-2	2-3	2-3	2-3	1-2	3-4
St. Mary Maligrad Isle	40°79'21" N 20°93'42" E	2-3	2-3	3-4	3-4	3-4	3-4
Eremitic Church St. Mary of Depth	40°88'40" N 20°96'37" E	4-5	4-5	4-5	4-5	3-4	0-1
St. Nicholas Monastery in Mesopotam	39°54'21" N 20°06'01" E	3-4	4-5	3-4	3-4	3-4	3-4

The European standard EN 15757:2010 is offering specifications for temperature and relative humidity to limit climate-induced mechanical damage in organic hygroscopic materials (CEN/TC 346 -Conservation of cultural property 2010; 2011) describes a methodology to establish allowable fluctuations based on the historical climate (Leijonhufvud and Broström 2018). It is based on the assumption that objects in the collection have adapted to their environment and that by limiting deviations from the historical climate there will be less risk for further damage (Leijonhufvud and Broström 2018). In contrast to many other standards targeting the preservation indoor climate, it is exclusively focusing on mechanical damage in organic hygroscopic materials. The method to establish allowable RH fluctuations in EN 15757:2010 is based on the climate history of a specific building. Rather than specifying a constant target level for the whole year or season, this method is based on a moving seasonal average around which variations should be limited. The mean target value for RH is calculated as a moving average over a 30-day period, from measurements for at least one year. The aim is to eliminate harmful fluctuations in relation to the historical climate (Leijonhufvud and Broström 2018).

The conservation and restoration of art works in Albania has been considered as an interdisciplinary approach (Meksi 1988; Gega and Meksi 1989). The particularities of post byzantine churches have been highlighted, while the importance of mural frescoes and other artworks is seriously threaten by the influence of environment and biological factors (Shumka *et al.* 2013). The scientific research on bio-deterioration of works of art is known for over several decades, while in the last decades the surveys and proposals for adequate conservation techniques of monuments have significantly advanced (Maxim *et al*. 2012). It was demonstrated that the preference of microorganism for some category of substrate is related to their susceptibility (Shumka *et al.* 2017; Meksi 1988; Guilliette and Dreesen 1995; Miller *et al*. 2006; Cámara *et al.* 2008). During the past decade studies reveal that in post byzantine churches of Albania fungal attacks appear when improper conditions of maintenance, humidity variation exist and other environmental factors for the churches (Shumka 2013; Shumka *et al.* 2017). Similar surveys confirmed the same results (Moza *et al.* 2012; Valentin 2001; Karabin 1997).

2. Methodology

The St. Mary's Monastery, also known as the Monastery of Dormition of Theotokos Mary, is a medieval Byzantine church in Zvërnec Island inside the Narta Lagoon, southwest of the city and to the South-western Albania (40°51'38" N 19°39'45" E). The old church of St. Marry in Bishqethem Lushnja, dedicated to Christ's ascension, is one of the important post Byzantine churches, located in village of Bishqethem, of the southwester part of Myzeqeja, near the city of Lushnja (40°51'38" N 19°39'45" E).

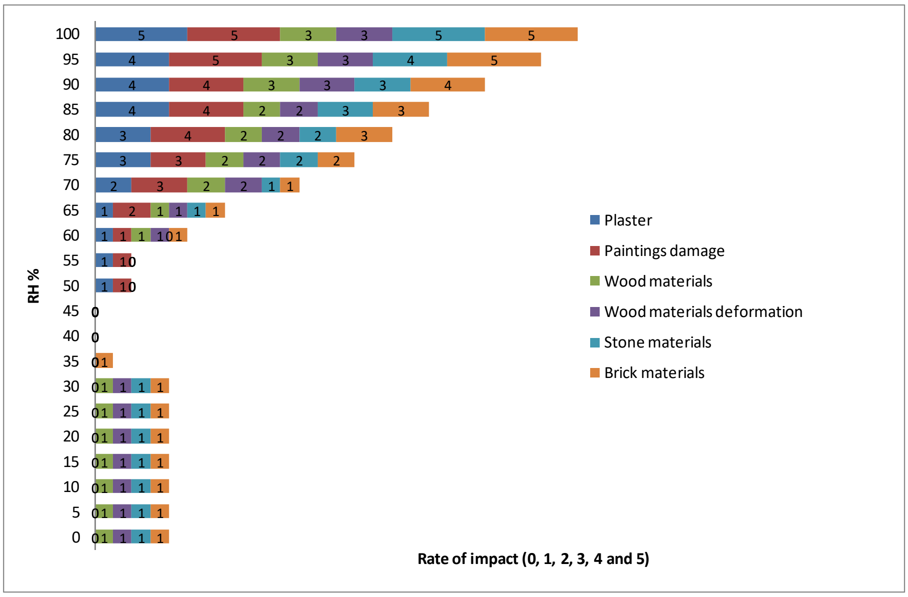
The St. Nicola Church in Shelcan Elbasan with its spectacular interior completely covered with frescoes by Onufri and belongs to 15th century (41°3'40"N 20°8'3"E). The locations of other considered objects are as following: the St. Thanasios in Karavasta (40°87'89" N 19°47'74" E), The Monastery church in Ardenica (40°81'87"N 19°59'26"E), St. Mary Maligrad Isle in Lake Prespa (40°79'21"N 20°93'42"E), Eremitic Church St. Mary of Depth (40°88'40"N 20°96'37"E) and St. Nicholas Monastery in Mesopotam (39°54'21"N 20°06'01"E). The temperature and relative humidity data were collected from the archival data of Institute of Geo-Science Tirana. Further on experimental tests through temperature and humidity were determined using data loggers from selected walls of both churches. Air temperature and relative humidity were measured every 30 min and processed to obtain average, maximum, and minimum monthly data.

The current effects of relative humidity and temperature oscillations were based on assessment as following: 0-1: very low impact; 1-2: low; 2-3: average; 3-4: high and 4-5: very high (Table 1), while the cumulative effects of RH (%) on different components as: plaster, paintings, wood materials, wood materials deformation, stone and brick was done based on rates: 0-no impact; 1-very low; 2-low; 3-average; 4-high and-5 very high (Figure 1 and 2).

3. Results and Discussions

The effected of relative humidity (Erhard *et al.* 1994) and relative humidity & temperature (Thomson 1986; Shumka *et al.* 2007; Shumka 2013; Atkinson 2014) has been connected with many aspects of degradation of different monuments and cultural objects. The effects were recorded to have serious sequences in different material including plaster, paintings (mural frescoes, etc), and wood materials, deformation of wood materials, stone and bricks (Figure 2). In our circumstances ones it comes to relative humidity and temperature oscillations, the threshold of 70-75% (RH) rapidly accelerates the development of moulds (Erhard *et al.* 1995; Shumka 2013), and these values are well correlated with degradation and deterioration of different materials and entire structures (Figure 2).

Figure 1. Cumulative effects of RH (%) on different components of the assessed objects (Rates: 0-no impact; 1-very low; 2-low; 3-average; 4-high and-5 very high)

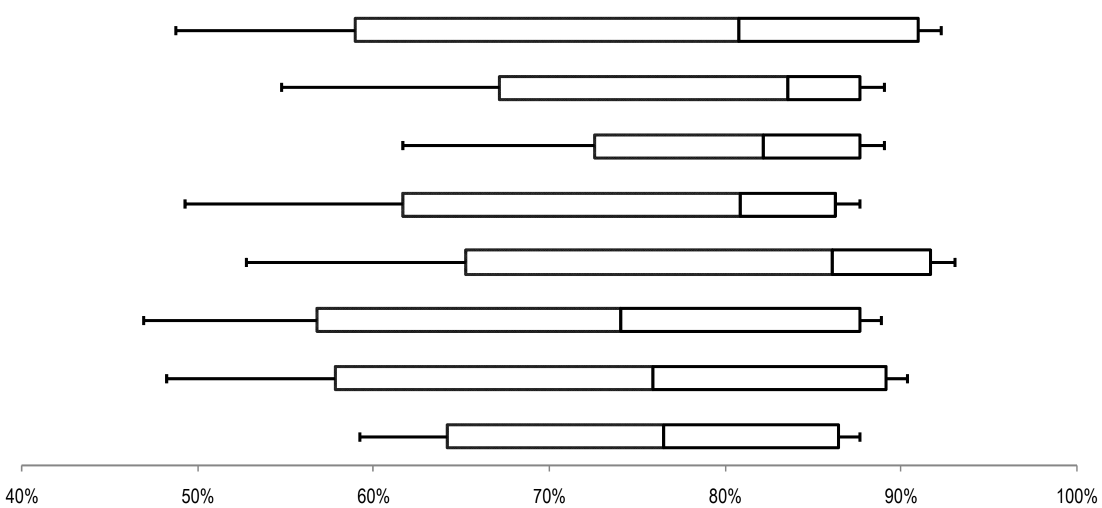


At the current circumstances there is a lack of standards in preserving indoor environment of the important pot byzantine monuments in Albania. Having in mind very particular interior and serious damages, an initial approach towards assessment of the environmental risk has both theoretical and practical importance. In the table 2 are described of values of temperature and relative humidity in three selected churches in Albania and excided limit following different references expressed in %. Following Thomson (1986) and ASHRAE (2007) and ASHRAE (2011) the limits are excited respectively with maximum 35%-30% with reference to relative humidity, showing a clear risk and demand for proper implementation of conservation measures. Process standards are widely used for quality management and for managing risks in organizations (Leijonhufvud *et al.* 2018). They generally do not require compliance with an objective or a specific result. Instead, they standardize procedures, duties and roles.

Following the assessments presented in Table 1, Figures 1 and 2 there is a correlation among increased rate of RH (%) and temperature oscillations with recorded damages on different components of analyzed cultural monuments.

The results mentioned above are compared to a recent report on the condition of these churches (Shumka 2017). According to this publication some traces of fungal growth were encountered in high abundance in St. Mary; Interior environment in St. Nicola showed minor degradation, fitting well with les RH fluctuations. Mould growth was found in both wall and on wooden materials.

Figure 2. Box plot records of minimal, mean and maximum values of RH (%)



Churches from top to down: Monastery of Dorm. of Theo. Mary, Narta; St. Mary in Bishqethem; St. Thanasios in Karavasta; St. Nicola Church in Shelcan; Ardenica Monastery; St. Mary Maligrad Isle; Eremitic Church St. Mary of Depth; St. Nicholas Monastery in

Based on wide experiences the churches can be used as a case study with the objective to identify opportunities and challenges with contemporary standards for churches and other monuments of culture in Albania. Through combination of qualitative approaches of how indoor climate control is managed with a discussion of the use of existing outcome-oriented standards in other countries for churches we intend to orient technical contexts in which standards has to be considered.

Conclusion

The control of relative humidity is of primarily importance for conservation approaches of the medieval monuments. On the other hand, it is hard to precise an ideal relative humidity of certain objects, since it varies from the location, climate conditions, landscape and materials of construction. Extreme oscillations and rapid large changes must be avoided one's indoor environment needs to be preserved. Based on our data the values of 30-65 % of relative humidity seems to be the most appropriate intending to minimize the effects on different components of a construction.

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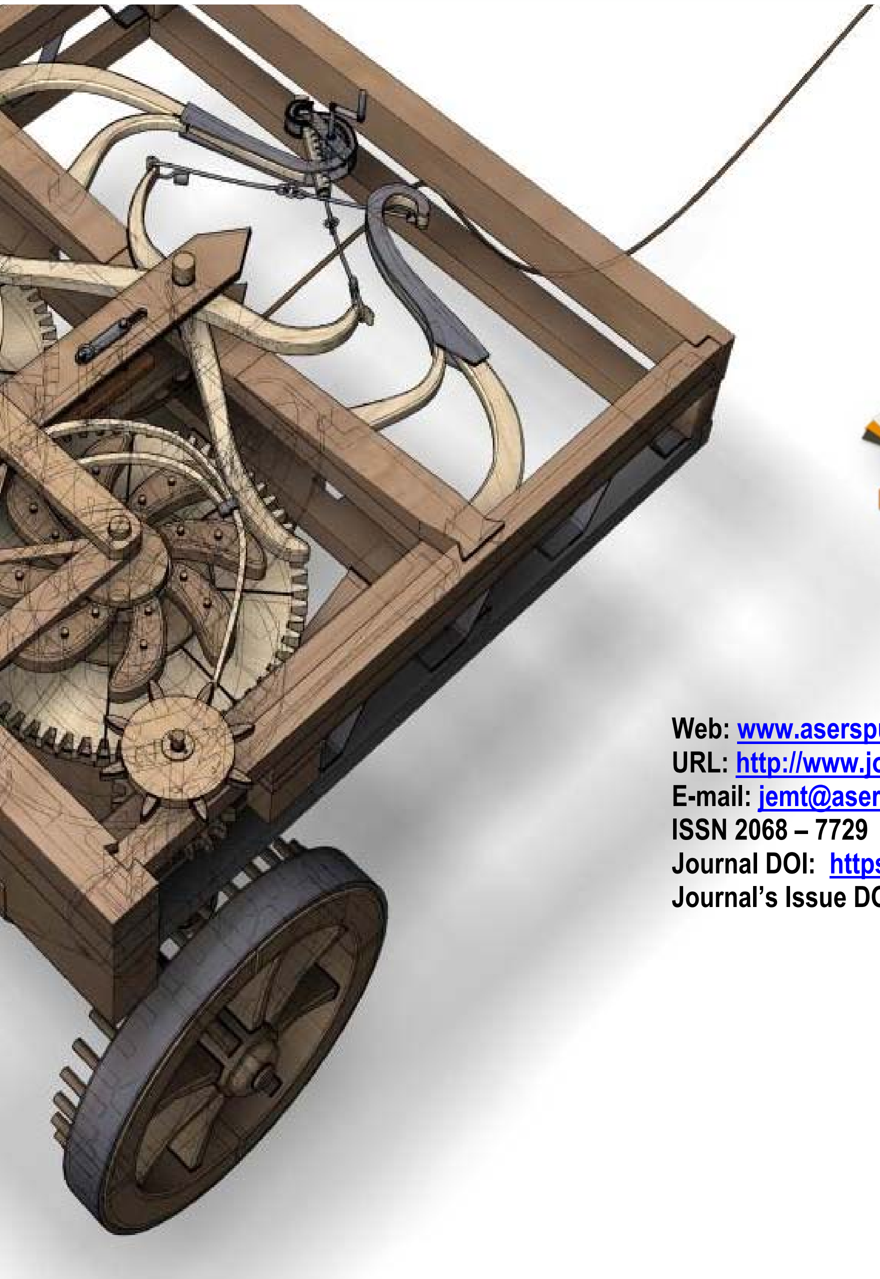

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