THE IMACT OF CLIMATE CHANGE ON BUILT HERITAGE IN SERBIA

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Summary: *Although climate change attracts wide interest at research and policy levels, little attention is paid to its impact on built heritage. In a period when Serbia tries to enhance regulation in the field of cultural heritage and to improve standards according to the European demands, it seems important to explore how the threat of climate change to cultural heritage can become better recognized and perceived as relevant. The paper deals with three global topics: data about climate change, the impact of climate change on the historical building materials and structures, and with the strategy how to prevent damages.*

Keywords: *Built Heritage, Climate Change, Relevant data, Impact, Preventive Strategy.*

1. INTRODUCTION

Although climate change, in last few decades, attracts wide interest at research and policy levels, little attention is paid to its impact on cultural, especially built heritage. In a period when Serbia tries to enhance regulation in the field of cultural heritage and to improve standards according to the European demands, it seems important to explore how the threat of climate change to cultural heritage can become better recognized and perceived as relevant. It is important to stress that for the first time cultural heritage is threaded as a non-renewable resource, to be transmitted to future generations, in the Spatial Plan of the Republic of Serbia, adopted in 2010. In the SWOT analysis done for the Spatial Plan of the Republic of Serbia in 2010, it was noted that one of the weaknesses in the field of cultural heritage is the lack of global strategy in the conservation, governance and use of built heritage. An opportunity was missed to introduce into the strategy the process of standardization for protection of cultural heritage endangered by Climate Change.

Rather than examining the fate of individual historical building, it is more important to take a strategic overview of the changing pressures on built heritage. As there is no systematical research of this topic in our country, we have to learn from European

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experience. The results can be incorporated in our legislation and practice where appropriate. Most of European countries have already prepared vulnerability atlases and accompanying guidelines. Those countries have also studied the effects of future climate variations on cultural heritage, producing in advance the measures that could use the knowledge of the climate science to anticipate the potential damage to our material heritage. [1] Scientists have assembled a growing body of evidence showing that human activities play an important role in the extent of change of the earth's climate. This warning has led international, regional, and national organizations to develop dedicated programs to asses and ménage the impact of climate change.
The impacts of Climate Change are affecting many and are likely to affect many more built heritage properties in the years to come. The national cultural preservation service has to work hard on several serious topics. They have to start with few requests such as:

- To review the nature and scale of the risks posed to built heritage properties arising specifically from Climate Change;
- To jointly develop a strategy to assist national and local governments to implement appropriate management responses; and
- To prepare specialists how to predict and manage the effect of climate change on built heritage. [2]

2. HOW CLIMATE CHANGE INFLUENCE THE DAMAGES OF BUILT HERITAGE IN SERBIA?

It is very difficult to make any general conclusion on this problem, as there is no serious analysis, studies or reports on impacts and implications of climate change on cultural heritage. Even our knowledge on different categories of climate change in Serbia is fragmentary. It is obvious that for now Serbia is not suffering from the most serious climate change, such as North and South America, Northern Europe and Northern and Central Asia. In scientific literature climate change is described by using several key indicators, such as greenhouse gas composition (especially CO_2), surface temperature, precipitations like rain, snow and hail, snow cover, sea and river ice, glaciers, sea level, climate variability, and extreme weather events. [3] For Serbian region, glaciers, sea level, sea ice are indicators than have no direct influence as yet. But, the extent of future temperature increase, that could be registered even now all over the Balkan, is difficult to project with certainty since there is very few and incomplete data of this process. The socio-economic factor that will influence the magnitude of such increases in the future is also elusive. [4]
Drying has occurred in the Mediterranean and Serbia suffers this influence, based on observations for the period since 1999. Floods are not as extensive as they are in surrounding countries, such as Romania, Croatia, Hungary, but they endangered some regions of Serbia every year. Strong storms are rare and passing, but are likely to become unforeseen and more intense.
Anthropogenic warning and see level rise would continue for centuries due to the timescales associated with climate processes and feedbacks even if greenhouse gas concentrations were to be stabilized.

As there are few or no data about climate change effects on the cultural heritage in Serbia, the research has to start by determine of meteorological changes which are critical to the built heritage in our country. [5]Research activities have to be focused first on defining the parameters of future climate variables related to temperature such as: range, thermal shock, freeze and thaw. In this part we could relied on the first international results which show that there will be a decline in the frequency of freezing over the twenty-first century and a lower potential for frost damages. Next part will be the process of defining the parameters for future climate variables based on water change influence such as torrent, sedimentation, humidity cycles, time of wetness, and dryness. Very important is to define long-term meteorological changes that have great impact on the built heritage.[6]

Figure 1. Flood around the tower Nebojsa-Belgrade fortress [*after 6*] *Figure 2. High level of Danube river and flood around the ramparts of Petrovaradin fortress* [7]

Figure 3. Landslide in vicinity of Belgrade [8] *Figure 4. Landslide endangering prehistoric archaeological site Vinca* [9]

The data, research results and mapping have to be further compared with the already prepared climate map for Europe in which the climate parameters are selected as most important for the protection of the built heritage. In the European Noah's Ark Project two baseline periods are important for us: near future (2010-2039) and far future (2070-

2099). The results show that climate change occurs over long-time scale and could be very subtle.

Figure 5. Church in Grabovo – the bell tower destroyed by stormy wind in 2009. [*10*]

Yet, some climate parameters such as humidity cycles, wind driven rain and freezing can change by large amount. That means that built heritage can be at risk even though changes in average temperature or precipitation amount are rather small.

3. IMPACT OF CLIMATE CHANGE ON HISTORICAL BUILDING MATERIALS AND STRUCTURES

Serbian Law on Cultural Heritage adopted in 1992/94 recognizes four different categories of immovable cultural goods: Archaeological Sites, Cultural Monuments, Historic Landmarks and Spatial Cultural-Historical Units. All of them could be subject to the direct influence of climate change.

Evaluation of the climate change impact on the built heritage could be done only if the selection of building materials is based on priority criteria considering the frequency of use, the avialability of results of dose-response or damage functions and the sensitivity to climate factors.

Opposite of the most European countries, where stone materials were most frequently used even for civil architecture, buildings in Serbia were made of earthen materials for centuries. But, stone materials were used for monumental buildings (chuches, town-halls) which represents the predominant group of cultural monuments of out standing value.

Immovable heritage of Serbia was mainly built of materials that are in use since prehistoric times and antique. Only few materials were introduced through medieval age, such as stained glass. Most frequently used materials in Serbia were:

- Earthen materials/ adobe, sun-dried bricks, bricks, tiles, mud mortar;

- Diferent kinds of wood / especially oak-wood, conifer, pine-wood, beech-tree, ash wood, elm-tree wood and white-poplar;
- Stone materials/ limestone, sandstone, marble, lime mortar;
- Metals/ iron, copper, bronze, zinc, lead and at last carbon steel.

Based on the European experience and collected in situ data, an extensive review of damage functions could be undertaken for above numbered building materials. New functions, including dose-response ones are currently developed and they involve serious environmental parameters in combination with climate forming gaseous pollutants (SO_2, NO_2, HNO_3), particulate matter (PM10, chloride deposition), pollutants in precipitation (acid rains).

Archaeological evidence is preserved in the ground because it has reached a balance with the hydrological, chemical and biological processes of the soil. Short and long cycles of change to these parameters may result in a poorer level of survival of some sensitive classes of material. [11]

Historic buildings, cultural monuments, have a greater intimacy with the ground than modern ones. They are more porous and draw water from the ground into their structure and lose it to the environment by surface evaporation.

Their wall surfaces and floors are the point of exchange for these reactions. Increases in soil moisture might result in greater salt mobilisation and consequent damaging crystallisation on decorated surfaces through drying. Timber and other organic building materials may be subject to increased biological infestation such as migration of pests in altitudes and latitudes that may not have been previously concerned by such threats.

Flooding may damage building materials not designed to withstand prolonged immersion, and post flooding drying may encourage the growth of damaging micro-organisms such as moulds. Archaeological sites and cultural monuments may be at risk from flooding, particularly the eroding effect of rapid flowing water. Increases in storminess and wind gusts can lead to structural damage.

Desertification, salt weathering and erosion is threatening cultural heritage in some parts of Vojvodina.

Damage function has to be further investigated trying to select the most suitable ones for assessing the effects of global climate change. Those climatic parameters are temperature, relative humidity, precipitation and wind velocity. [12]Climate change has to be taken into account when trying to evaluate its impact on interaction between biological particles and surfaces of historical buildings. A review focusing on biodiversity, i.e. the species colonizing different materials, especially stone elements, is great importance because small alterations in microclimate, affecting temperature and precipitation may produce significant changes in the composition and structure of dangerous biocommunity.

To understand the response of materials to extreme climate change all historic materials have to be constantly under surveillance to determine the potential modes of material damage induced by climate change.

Climate Change Risk Indices due to the biodeterioration are already systematizated and available in the various technical guidelines and handbooks. Those indices help to establish the relations between climate change causes, damage consequences and necessary measures to protect against climate.

4. NECESSARY MITIGATION STRATEGY FOR CLIMATE CHANGE IMPACTS

All European projects and documents dealing with climate change hazards and risks they could provoke insist on the necessity to develop strategies for mitigating and adapting to the global climate change impact on built heritage. After two firs steps, identifying the climate parameters and assessing the respective changes over the hundred year, and recognizing all possible treats to building materials, surfaces and structures, drying out and structural damages are in the focus of mitigating strategies.
After the range of different building simulation programme which has been reviewed, the public domain software programme Energy Plus has been widely recommended as the most appropriate programme for the simulation of the hydrothermal environment of built heritage. Energy Plus is a whole building energy simulation program that engineers, architects, and researchers use to model energy and water use in buildings. Modeling the performance of a building with EnergyPlus enables building professionals to optimize the building design to use less energy and water. Programme takes as input the physical properties of the building and a weather file giving the annual local climate conditions, and is also able to compute dew points, surface temperature and surface relative humidity. The process simulates the building's indoor environment, which is the result of the interaction of the external climate conditions and the physical properties of the building. The same programme use indoor and outdoor temperature and relative humidity to validate the model.
Another simulation programs are developed to simulate the water penetration and drying properties in many useful case-studies of historic buildings.
Prevention strategies could be best formulated when are focused on the problems generating the most dangerous effects caused by climatic issues such as weathering degradation in combination with rain and wind, strong winds, heavy rains, floods and landslides. Continuous analyses and archive records on structural and building failures can help to propose global frame for solving the individual problems of the sensitivity of historic materials and structured exposed to weather and disaster action; the static and dynamic loading of historic structures due to air flow and strong winds, and integrated risk of flood damage. The strategies must encompass the models of subsoil behavior for landslides prediction to avoid subsoil instability and damage consequences.
Data and maps achieved through different European research project points out that the most important climate parameters relevant to building damage and degradation could undergo significant changes in the 21th century. This, not so bright perspective for the cultural heritage future, open the way for creation the specific heritage climatologies.

5. FINAL REMARKS AND CONCLUSIONS

As all other European cultural heritage, built heritage in Serbia suffers a consequence of increasing atmospheric temperatures (‘global warming’), and additional changes in geophysical features are expected. Some of those changes could be registered even now. They are change of precipitation patterns, change of the frequency, intensity and

seasonality of extreme events such as droughts, fires, heavy precipitations, floods, and storms. Climate change has implications for different natural and societal systems including cultural and natural heritage. The assessment of the impacts of Climate Change on built heritage must account for the complex interactions within and between nature, culture and society. Changes to cultural heritage caused by climate change cannot be viewed separately from changes in society, demographics, people's behaviour, the impact of conflicting social values and land use planning which will also need to evolve in the face of climate change. Cultural heritage is now defined very widely to include not only individual sites, buildings or structures but also urban or rural landscapes in process which may include dynamics that are not only subject to climate change but also contribute to climate change.

Climate change will have physical, social and cultural impacts on cultural heritage of Serbia. It will change the way people relate to their environment. This relationship is characterised by the way people live, work, worship and socialise in buildings, sites and landscapes with heritage values. Climate change and the socio-economic changes that will result will have a greater possible impact on the conservation of cultural heritage than climate change alone. This combined effect is not yet recognised in the strategies for monitoring, governance, presentation and use of cultural heritage in Serbia. The problem needs to be explored more fully and this can be done in the context of preparations for adopting the new Law on Cultural Heritage.

Many of built heritage examples are living places which depend on their communities to be sustained and maintained. Climate change has consequences for the whole of human existence and the products of human creativity. In the case of built heritage these consequences will be manifest in at least two principal ways: direct physical effects on the site, building or structure and the effects on social structures and habitats that could lead to changes in, or even the migration of, societies that are currently sustaining those examples. The implications of the latter are not well understood, even if the nature of the impacts will vary depending on the nature of the built heritage category.

The character of cultural heritage is closely related to the climate. The urban landscape and the built heritage have been designed with the local climate in mind. The stability of cultural heritage is, therefore, closely tied to its interactions with the ground and the atmosphere. Where built heritage is in use by local communities there may be pressure for significant adaptive changes to allow use and occupation to continue. Even where this is not the case, there can be very direct physical effects. [13]

In the context of complex interactions such as mentioned in the paper, one needs to define indicators to assess the overall impact of climate on built heritage. Climate change can be subtle and can occur over a long period of time. However, some climate change parameters such a freezing, temperature and relative humidity shock can change by large amounts over a short period of time. To identify the greatest global climate change hazards and risks they can provoke by their impacts on built heritage, the community, local and state governments have to be well prepared. [14]

The strategy could be on the strategy developed after the detailed analysis of the various issues elaborate in the report on "Predicting and Managing of Effects of Climate Change on Word Heritage" prepared in 2012. In this Report actual term Conservation means the management of change, and the climate change is treated as one of the most significant

global peril facing society and the environment in 21th century. According to proposed strategy the actions that need to be taken to safeguard heritage are threefold:

- Preventive actions: monitoring, reporting and mitigation of Climate Change effects through environmentally sound choices and decisions at a range of levels: individual, community, institutional and corporate.
- Corrective actions: adaptation to the reality of Climate Change through global and regional strategies and local management plans.
- Sharing knowledge: including best practices, research, communication, public and political support, education and training, capacity building, networking, etc.

All mentioned actions are suitable to be implemented in our strategy and practice without any correction.

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УТИЦАЈ КЛИМАТСКИХ ПРОМЕНА НА ГРАДИТЕЉСКО НАСЛЕЂЕ СРБИЈЕ

Резиме: *У раду се разматрају подаци о климатским променама, утицај климатских промена на историјске материјале и конструкције и стратегија.*

Кључне речи: *Градитељско наслеђе, утицај климатских промена, стратегија*

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