International Course on Stone Conservation SC13

SESSION: Environmental factors of deterioration

INSTRUCTOR: Peter Brimblecombe

TIME: Tuesday, 14th May/ 14:30-16:00 (1.5 hours)

SESSION OUTLINE

ABSTRACT

It has long been recognized that the environment exerts a wide range of pressures on building stone. These can be loosely thought of in terms of the physical pressures of climate, particularly water and temperature issues and the chemical attack by pollutants. The importance of time and weather as disruptive factors were readily understood, since the time of Vitruvius. This was significant in the case of stone buildings which were meant to last and architects wanted their creations to survive long periods. Nicholas Hawksmoor 's writings about his early 18th century restoration of Westminster Abbey reveal: "I am of the opinion, if violence does not happen, this fabrick will stand 1000 years"

Traditional climatology may not be the most useful approach to describing damage to stone. The geography of climate was outlined by Köppen in the 19th century, but his ideas were tuned to an interest in vegetation, so they have to be carefully adapted to explore the relationship between material heritage and climate. Normal meteorological variables of temperature and precipitation, while valuable in parameterising climate impacts on stone do not give a full picture, so it is advantageous to combine or accumulate simple meteorological data when assessing the effect of weather on building stone and other porous materials. As an example, temperature can be combined with other meteorological parameters to create new parameters to describe stone weathering. If temperature drops below zero then water within the pores of stone can freeze and expand, such that the change in liquid to solid phase can cause mechanical stresses that lead to frost shattering. Thus, even relatively small changes in temperature can cause significant change in the number of freeze thaw cycles (Grossi et al. 2007). This amplification can be seen when changes in humidity cause the brines within pores to form crystals (or change in crystalline form) exerting pressure within the stone that leads to salt weathering. Greater extremes in temperature can be found at stone surfaces exposed to intense sunlight where temperatures can exceed 50°C. Such intense exposure to solar radiation can exert stress on some stones such as granites, where different minerals can absorb different amounts of radiation and differential expansion can place stress on the stone (Bonazza et al. 2009). When temperatures change rapidly 2° per minute this can produce thermal shock damage.

Precipitation is an important parameter because the dissolution of stone is strongly dependent on precipitation amount (Lipfert 1989). It can also act along with other meteorological parameters such as wind speed to create wind driven rain. This can force water deep into porous building materials or wash pollutant crusts off building surfaces as disfiguring patterns. Wind driven sand is also possible in arid regions where it can abrade friable rocks or earthen building materials. Water is also relevant when combined with temperature to the promotion of biological growth on monuments. It is not only liquid and solid water than can contribute to the deterioration of stone, but of equal importance is water vapour and relative humidity, particularly in relation to salt weathering.

The IPCC Fourth Assessment Report: Climate Change 2007 (AR4) suggested that over the next two decades global temperatures would increase by about 0.2°C per decade independent of the emission scenarios chosen. Best estimates for the temperature change by the final decade of the 21st century compared with the period 1980-1999 ranged over increases of 1.8-4.0 °C dependent on the scenarios chosen. Regionally these increases in temperature may differ significantly, with some of the largest predicted increases for northern latitudes. Precipitation is typically predicted to increase in tropical high rainfall areas, with general decreases in the subtropics. Rainfall may nevertheless be more intense, even where total annual amounts decline. This has meant that some historic buildings have been renovated to increase the capacity of drain pipes and guttering.

Buildings were once blackened by coal soot, but now mostly diesel particles and in the future, wind-driven rain may alter the patterns and oxidation of surface organics. Blackening patterns that outline or shadow architectural elements are publicly more acceptable than those that cut across them e.g. rain streaking. In recent years more airborne particles have become dominated by organic pollutants and a yellowing process has become evident. Add to this the effect of alterations biological growth which can cause a significant change in the appearance of buildings.

OBJECTIVES

- Discuss critical climate pressures on porous materials
- Define heritage climates
- Consider changes in climate pressures over time
- Explore the nature of aethstic damage through soiling

CONTENT OUTLINE

Factors that damage monuments and cultural heritage

- classical understanding
- freeze thaw cycles and long term climate change becomes relevant

The nature of climatology

- heritage climates
- Wladimir Peter Köppen c1900 studied plant-climate interactions
- specialist climatologies
- heritage and risk climatologies
- Koppen flaw wind driven coastal chloride
- sea salt weathering of porous stone near coasts

Impacts of meteorological factors on materials

- summer precipitation and dry summers
- increase in very wet days
- middens in greenland
- rust on svalbard
- contemporary architectural impacts
- biological damage

Climate change and critical parameters

- combinations
- accumulations
- variation/cycles/events
- risk expressions

- sociological/managerial contexts
- freeze thaw cycles
- salt damage
- phase change and amplification
- future English dryness and damp
- wind driven rain
- wind driven sand

Aesthetic damage by blackening and discoloration

- coal black buildings of the past
- 21st c blackening of buildings
- soiling perception:
- yellowing of buildings
- aesthetic damage by blackening and discoloration

READINGS

🕮 = Essential reading material

💻 = Available online

🕮 Brimblecombe, Peter. 2010. Heritage Climatology. In *Climate Change and Cultural Heritage: Proceedings of the Ravello International Workshop, 14-16 May 2009 and Strasbourg European Master-Doctorate Course, 7-11 September 2009*. edited by Roger-Alexandre Lefèvre and C. Sabbioni. Vol. Scienze e materiali del patrimonio culturale. 54-57. Bari: Edipuglia.

🕮 Brimblecombe, Peter. 2010. Heritage Climatology. In *Climate Change and Cultural Heritage: Proceedings of the Ravello International Workshop, 14-16 May 2009 and Strasbourg European Master-Doctorate Course, 7-11 September 2009*. edited by Roger-Alexandre Lefèvre and C. Sabbioni. Vol. Scienze e materiali del patrimonio culturale. 73-78. Bari: Edipuglia.

💻 Bonazza, A., Sabbioni, C., Messina, P., Guaraldi, C., De Nuntiis, P. Climate change impact: Mapping thermal stress on Carrara marble in Europe. *Science of the Total Environment* 407, pp. 4506-4512 (2009).

💻 Grossi, Carlota M., Peter Brimblecombe, and Ian Harris. 2007. Predicting Long Term Freeze-Thaw Risks on Europe Built Heritage and Archaeological Sites in a Changing Climate *The Science of the Total Environment* 377 (2/3): 273-81.

Sabbioni, C., Brimblecombe Peter, and May Cassar. 2010. *The Atlas of Climate Change Impact on European Cultural Heritage: Scientific Analysis and Management Strategies*. Ec Cultural Heritage Research Series. London and New York: Anthem.