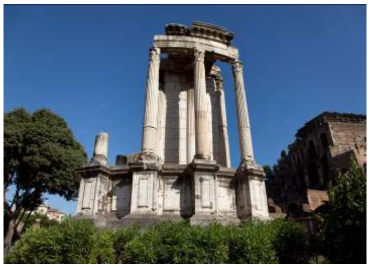

International Course on Stone Conservation SC13

SESSION: Air pollution and the interaction of water and porous building materials

INSTRUCTOR: Peter Brimblecombe

TIME: Tuesday, 14th May/ 16:30-18:00 (1.5 hours)

SESSION OUTLINE

ABSTRACT

Although early architects recognised the importance of weather in damaging building surfaces, they were also worried about the impact of air pollutants. At first this was simply seen as the disfiguration caused by smoke. Horace complained of the smoke begrimed temples in ancient Rome. Damage by acidic coal smoke came to be very important in the 19th century because cities burnt so much coal. In the 20th century this became a key concern in the 1930's and by the second half has shifted to attack by acid rain. In the future weathering by meteorological factors is likely to be the most important mechanism of degradation.

Porous materials are readily damaged by water, particularly through the processes of frost damage and salt weathering. Hydrated salts produce higher crystallisation pressures during thermo-hygrometric cycles compared to unhydrated salts. Porosity and pore morphology have a great influence on salt weathering. Many stones traditionally used in the built heritage (e.g. Gothic cathedrals) have high porosity and low strength, so are particularly susceptible to salt decay, and the climate changes of "Gothic Europe" may be especially important.

In London, even though coal was adopted by the city as a fuel very early, the deposition of pollutants was dominant 1750-1950 (in London) and recent improvements to air quality reflect the benefits brought by local regulation of acidic emissions. Although recent experience established the importance of pollutants as a source, longer time perspectives remind us that such situations are not static and recession in stone may once again be dominated by climate rather than pollution.

The presence of gypsum crusts on damaged buildings is an importantindicator of the key role played by sulfur compounds:

$$SO_2 + H_2O \rightarrow H_2SO_3$$
$$H_2SO_3 + CaCO_3 \rightarrow CaSO_3.\ \tfrac{1}{2}H_2O + CO_2 + \tfrac{1}{2}H_2O$$
$$2CaSO_3.\ \tfrac{1}{2}H_2O + O_2 + 3H_2O \rightarrow 2CaSO_4.\ 2H_2O$$

The transformation of calcium carbonate minerals in the stone to gypsum causes some dramatic changes. Gypsum is more soluble than the carbonates so in rain washed areas it can be removed via dissolution. Additionally gypsum has a much higher molecular volume than the carbonate mineral. This induces mechanical stresses in the stone and the resultant expansion of the corroding black surface layers can be seen as an efflorescence that peels outward from damaged facades. Nitrogen compounds and ozone are more characteristic of the modern urban atmosphere, so it is also important to consider their effects. Particulate material accumulates within crusts and they can now have an elaborate organic chemistry

The presence of modern diesel soot on facades is especially important as it dominates the soiling in some locations.

Thresholds of acceptability for blackening can be related to soot loading. When soot loading of the ambient air is high, e.g. near busy roads, buildings are dark and typically viewed as unacceptable

OBJECTIVES

- Discuss critical air pollutants pressures on porous materials
- Examine the mechanisms of damage and the forms it takes on building materials
- Assess the evolution of environmental pressures in a changing world

CONTENT OUTLINE

Water and pollution

- multiple risks appear different on various elements of buildings
- multi-risk mapping of pollution, frost and salt damage

Water and porous stone

- phase change and amplification
- freeze thaw cycles
- increase/decrease in frosts
- RH cycles and salt damage - salts can be hydrated and unhydrated
- Cathedral of St John thenardite-mirabilite weathering
- architectural style - salt damage and gothic
- fungal growth on wood
- wind driven rain

Urban pollution

- Westminster Abbey and limestone recession in London
- natural weathering increasingly important
- SO_2 - hard black sulfate crusts
- acid rain - white areas
- corrosion of iron
- other metals and polymers – effect of ozone
- architectural impacts of traditional pollutants
- sulfation by SO_2 - limestone to gypsum
- other gaseous pollutants and synergisms
- particles – surface area change so may be a change in the nature of soiling
- older thick crusts - organic carbon - EC elemental carbon
- stratigraphy of crusts in Venice
- modern urban deposits- less sulfur (phytotoxic) more nitrate (nutrient) and biological damage
- chemistry of crusts modern crusts from diesel are rich in organics
- crusts as polymers

READINGS

🕮 = Essential reading material

💻 = Available online

🕮 Brimblecombe, Peter, and Carlota M. Grossi. 2009. Millennium-long damage to building materials in London. *Science of the Total Environment* 407: 1354-61.

🕮 Brimblecombe, Peter. 2011. Environment and architectural stone. In *Stone in architecture*. edited by Siegfried Siegesmund and Rolf Snethlage, 317-46. New York: Springer.