

12. Impacts Of Acid Rain On Buildings

Introduction

In 1856 Robert Angus Smith wrote:

It has often been observed that the stones and bricks of buildings, especially under projecting parts, crumble more readily in large towns where coal is burnt....I was led to attribute this effect to the slow but constant action of acid rain.

Since the beginning of the Industrial Revolution soiling and degradation of buildings in urban areas has been noticeable. The cause of this has often been attributed to the effects of air pollution. The pollutants that form acid rain are principally sulphur dioxide and nitrogen oxides; both of these are released from the combustion of fossil fuels like coal and oil. Since the Industrial Revolution emissions of both have increased. UK Sulphur dioxide (SO₂) emissions peaked in the 1960s but have since declined by over 80%. In 1999 emissions of sulphur dioxide were approximately 1.2 million tonnes. Emissions of nitric oxides and nitrogen dioxides, collectively known as NO_x, have fallen since 1990; emissions in 1999 were around 1.6 million tonnes.



Despite the reduction in emissions there is no clear evidence that cleaner air has brought about a reduction in building degradation. In fact, buildings that have withstood thousands of years of weathering have in the last 25 years or so begun to deteriorate rapidly. This can be attributed to the permanent alteration of stone surfaces by

sulphation, a process whereby the exposed surface of limestone dissolves away as rainfall washes away the sulphated layers.

It is only in the last couple of decades that attempts have been made to quantify the amount of damage that has been caused to materials as a result of acid deposition. Concern about the effects of acid rain on building materials was raised in a House of Commons Select Committee report in September 1984. As part of the Government's response, the Buildings Effect Review Group (BERG) was established to give considered advice on the effects of acid deposition on buildings. It is only relatively recently that the spatial concentrations of acid rain pollutants and their transport mechanisms have become fully understood so more accurate estimates of the damage that may occur to buildings can be made.

Materials Affected

The list of materials affected by acid deposition is very long as most materials are liable to some degree of damage. Those most vulnerable are: limestone; marble; carbon-steel; zinc; nickel; paint and some plastics. Stone decay can take several forms, including the removal of detail from carved stone, and the build-up of black gypsum crusts in sheltered areas. Metal corrosion is caused primarily by oxygen and moisture, although SO₂ does accelerate the process. Most structures and buildings are affected by acid deposition to some degree because few materials are safe from these effects. In addition to atmospheric attack structures that are submerged in acidified waters such as foundations and pipes can also be corroded.

The Chemistry of Corrosion

Wet and dry deposition both contribute to the corrosion of materials. Dry deposition consists of gaseous and particulate matter that falls

to Earth close to the source of emissions causing direct damage. Sulphur dioxide often falls as dry deposition within 30km of its source. Wet deposition occurs when the pollutants are spread high into the atmosphere, where they react with water vapour in clouds to form dilute acids. The effects are felt much further afield and therefore wet deposition can affect areas that are many tens of kilometres away from any sources of pollution.

Calcium carbonate in certain stones dissolves in dilute sulphuric acid to form calcium sulphate:



This has two effects. Firstly it causes the surface of the stone to break up; secondly, a black skin of gypsum (calcium sulphate) forms which blisters off exposing more stone. When the gypsum crystals form they can grow into the stone, and the process may continue for up to 50 years. This is known as the Memory Effect.

Sulphur dioxide is the main pollutant in respect to corrosion but others also take their toll including NO_x, carbon dioxide (CO₂), ozone (on organic materials) and sea salt from sea spray. Research has revealed that when nitrogen dioxide (NO₂) is present with SO₂, increased corrosion rates occur. This is because the NO₂ oxidises the SO₂ to sulphite (SO₃) thereby promoting further SO₂ absorption. The Review Group on Acid Rain report in 1990 indicated that in remote areas wet deposition will predominate, whereas in Eastern England dry deposition will predominate. This finding is supported by a study of south-east England, which suggests that up to 40% of total damage is due to dry deposition.

The interactions between materials and pollutants are very complex and many variables are involved. Deposition of pollutants onto surfaces depends on atmospheric concentrations of the pollutants and the climate and micro-climate around the surface. Once the pollutants are on the surface, interactions will vary depending on the

amount of exposure, the reactivity of different materials and the amount of moisture present. The last factor is particularly important because the SO_2 that falls as dry deposition is oxidised to sulphuric acid in the presence of moisture on the surface.

Studies Undertaken

There are a number of studies that have been initiated looking at the effects of acid deposition on different materials. The National Materials Exposure Programme (NMEP) was initiated by BERG in 1987 and consists of 29 sites throughout the country. Samples of different materials are exposed at the sites for a period of not less than four years, during which time data on meteorological conditions and atmospheric conditions will be collected and corrosion rates monitored. The UK NMEP is also part of the International Materials Exposure Programme set up under the United Nations Economic Commission for Europe framework, in which materials are exposed to polluted environments in Europe and North America.

Examples of Damage

The effects of acid deposition on modern buildings are considerably less damaging than the effects on ancient monuments. Limestone and calcareous stones which are used in most heritage buildings are the most vulnerable to corrosion and need continued renovation.

Evidence of the damaging effect of acid deposition can be seen throughout the world. For example, world famous structures as the Taj Mahal, Cologne Cathedral, Notre Dame, the Colosseum and Westminster Abbey have all been affected.