Santiago Calatrava's auditorium in Tenerife, Spain: tinted concrete flecked with white ceramic.

Q&A Andrea Hamilton

Concrete conservator

Materials scientist and engineer Andrea Hamilton at the University of Strathclyde in Glasgow, UK, uses chemistry research to conserve the structural and aesthetic integrity of concrete. She talks about dams, nuclear-waste storage and an artwork that explores weathering.

NICK HIGGINS

How did you get interested in materials engineering?

I have a very emotional response to architecture. Cement and concrete can be seen as synonymous

with poverty and degradation, even war. But when I started to study it, I gained a greater aesthetic appreciation.

What are some examples of beautiful concrete structures?

The Catalan architect Antoni Gaudí used cement and concrete in novel ways. Rather than modular cookie-cutter structures, you see curvaceous, colourful forms because precast, reinforced concrete allowed him to push the boundaries of structural engineering. Stylistically, my favourite is an auditorium by Santiago Calatrava in Tenerife, Spain. Made from steel-reinforced concrete, it looks like a huge wave, curving downward into a narrow point, and its 3,500-tonne weight is supported by just five points of contact. The surface is reflective; Calatrava tinted the concrete using

titanium dioxide and decorated the surface with fine pieces of white ceramic.

Why is concrete so hard to conserve?

Cement is chemically complex — more so than any other building material. Portland cement, the most common type, is made from clay and limestone, heated to around 1,450°C. This forms clinker, containing at least 70% calcium silicate minerals, which is ground and mixed with a small amount of gypsum to create cement powder. Mixed with water and aggregate, that makes concrete. There are lots of variables involved, particularly in mix design. I have worked on the conservation of cement-rendered brick buildings at the East Fortune airfield in Scotland. Built during the Second World War, they were not intended to last. Frost damage has made the cement render peel.

How has ancient concrete survived?

The Romans must have experimented. They used lime mixed with volcanic ash, producing a relatively aluminium-rich system. Recent research has shown that Al-tobermorite [a calcium silicate hydrate mineral] formed in ancient harbour concrete such as a breakwater in Pozzuoli Bay near Naples. This

enhanced the concrete's durability, even in sea water. The Romans also added animal hair as fibre reinforcements, and blood for frost resistance — both excellent innovations.

How can we make concrete more environmentally friendly?

Every tonne of Portland cement produced generates about 1 tonne of carbon dioxide, half of it from the chemical reaction when you heat limestone. You can't avoid carbon dioxide coming off when you heat limestone, but you can control how much Portland cement goes into a mix. To me, the most promising research on the ecological side focuses on incorporating more industrial by-products. Up to 80% of the cement can be replaced with fly ash or slag, although it takes longer to set.

How can science aid concrete's longevity?

Early research explored the bulk mechanical properties of concrete. Now research tends to focus on microstructures and crystallography to tailor clinker reactivity. Controlling permeability is also essential, as one of the main problems associated with concrete and cement is water ingress. With colleagues at Strathclyde and the Nuclear Decommissioning Authority, I'm working on structures to house nuclear waste. One member of the project is developing smart sensors that can be embedded in concrete to detect properties such as water and chloride content, and temperature, in real time. My goal is to use this data to develop and feed a real reactive transport model of concrete deterioration.

Do concrete-rich countries such as the United States present particular challenges?

The dramatic feature of Frank Lloyd Wright's iconic 1930s house Fallingwater is reinforced concrete 'trays' cantilevered out over a waterfall; in the late 1980s the cantilevers had to be supported from within because they were sagging. Of US infrastructure, dams are an issue: their average age is 52 years; it could cost more than US\$50 billion to rehabilitate them all.

Are you working on any art projects?

I'm involved in *Salt Licks*, a fascinating project due to be built this summer on the Lincolnshire coast. It will be a 6.6-metre-high reinforced concrete construction, clad with salt blocks. The idea is that the salt will dissolve, allowing a dynamic shape to form. This represents a fantastically severe test of how concrete weathers in contact with salt. Time-lapse digital cameras will monitor it. We will see the immediate impact of driving rainfall, in patterns that have never been visible before. My interest is in informing new art. Once you have a bag of cement, aggregate and water plus guidelines, you can create almost anything, anywhere. ■

INTERVIEW BY ALEXANDRA WITZE