Scottish Construction Leadership Forum

Local Materials Case Study
Geopolymer concrete development

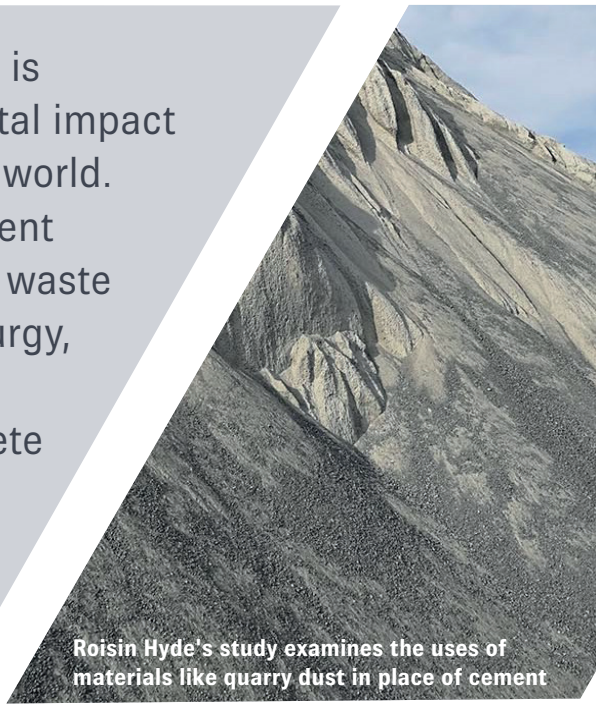
Local materials can contribute to geopolymer concrete creation wherever you are in the world.

Project: **To develop high-performance, low-impact concrete alternative**

A concrete way forward

A carbon-friendly concrete substitute made with local materials

Finding new ways to use waste materials is fundamental to reducing the environmental impact our built environments are having on the world. Architect, Fulbright Alumni and PhD student Roisin Hyde is developing a way of using waste materials from mining, quarrying, metallurgy, water purification, incineration and agriculture to create a sustainable concrete substitute. Which means that there's always going to be some kind of local source material available, wherever you are in the world.



Roisin Hyde's study examines the uses of materials like quarry dust in place of cement

"After fossil fuels, concrete is the biggest cause of CO2 emissions and damage to the environment."

Roisin Hyde, Architect, PhD researcher, Fulbright Alumni and TEDx Talker

THE BACKGROUND

Roisin Hyde began her career as an architect in 2001 and spent 15 years working on commercial and public projects for clients including Dublin City Council, the Sustainable Energy Authority of Ireland and Codema, Dublin's energy agency. She is now working with a Scottish-based collaboration to showcase the capabilities of geopolymer concerete at COP26 in Glasgow.

With an interest in conservation and sustainability, Roisin was struck by the limited range of affordable, high-performance, sustainable materials used in the construction industry. She also felt there had to be a better solution than simply adding to existing buildings, for example by retro-fitting solar panels or ground source heat pumps.

One of the main difficulties, however, in using materials that would be less damaging to the environment was that they tended to cost more than standard materials but perform less well. Roisin decided she wanted to find a better way – and went back to school, enrolling as a doctoral research student at Queens University Belfast's School of Natural & Built Environment.

MAKING USE OF LOCAL MATERIALS

Concrete is traditionally made by combining cement, aggregate and water. Cement production involves heating, grinding and milling limestone, a process which relies on the extraction of finite natural resources and emits almost a tonne of CO2 per tonne of product. Clinker production and energy used by the kilns, in fact, accounts for up to eight per cent of the world's carbon emissions. It also generates waste materials, which usually end up in landfill.

Roisin's work in Northern Ireland involved replacing cement and aggregate components with industrial by-products and waste – locally-sourced fly ash and quarry dust, for example. She was also interested in exploring materials in other geographic locations.

In 2018, she successfully applied for a Fulbright visiting researcher grant that allowed her to take her research further afield. Having read about the world's first geopolymer concrete cladding panels created by Dr Brett Tempest at University of North Carolina (UNC) in Charlotte, the US was her first port of call.

Dr Tempest's research had been done almost exclusively with coal fly ash. Roisin's work with him and with UNC built on that research to experiment with materials like ultra-fine granite, trap rock and basalt quarry dusts, smelter waste from steel recycling, silica fume and granulated blast furnace slag.

Both projects resulted in low-carbon, lightweight, ultra-strong concrete. Unlike conventional OPC, which consists of a calcium silicate hydrate matrix, the geopolymer cements have a unique repetitive inorganic polymer nanostructure. That makes them resistant to chemicals, stable at high temperatures and very strong.

> *"My model is to look at what's available locally. I analyse by-product and waste for suitability as supplementary cementitious materials, which can be used to replace up to 90% of the cement and aggregate content in conventional concrete."*
>
> **Roisin Hyde**

In fact, as part of her PhD research, Roisin was able to create an ultra-high performance mix from 96% by-product and waste material with 75% less CO2 than conventional concrete. In terms of actual performance it withstood pressures of around 140 MPa, making it three to four times stronger than regular concrete.

What's more, the rapid setting concrete mix, once created, can be used to 3D-print modular construction components. Traditional methods use different moulds to create individual components. Once they're cast, the moulds are discarded. 3D printing allows every component to be created on the same machine, with no wasted materials or moulds to dispose of. It also guarantees quality, since every component produced will be identical to others.

> *"It's a more sustainable way of doing things. Right now we extract virgin materials to turn into concrete. With this new method, we reuse and recycle. So we're protecting the environment by extracting less raw material and reducing waste materials and infill."*
>
> **Roisin Hyde**

USING MATERIALS LOCAL TO ANYWHERE

Roisin believes there's an almost infinite variety of materials that could be used in place of aggregates or cement, some as they occur naturally and some as waste or by products of industry, as well as certain recycled materials.

Her research will go on to examine the viability of water purification waste, volcanic ash, certain kinds of clay or sand, slags from the metal industry and ash from incinerators. She'll also look at by-products from mining and quarrying, as well as recycled glass, ceramics and agricultural waste from stalky plants like barley and wheat.

The ultimate goal is to develop a materials analysis and processing model which will allow Roisin to travel anywhere in the world and produce high performance, low carbon concrete using local waste materials.

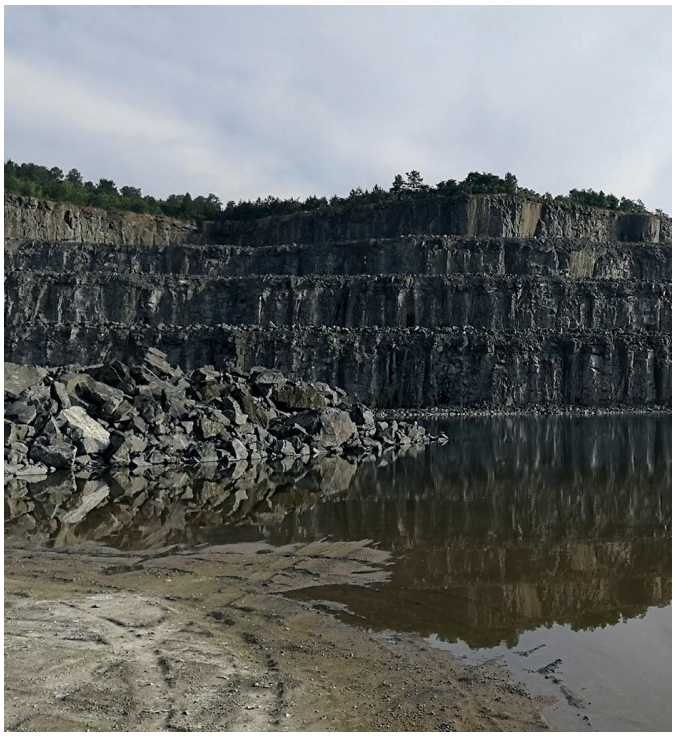
SHOWCASING LOCAL MATERIAL USE ON AN INTERNATIONAL STAGE

The world will have an opportunity to view Roisin's work at the United Nations Climate Change Conference (COP 26) in Glasgow in November 2021.

She's working with a team comprised of Scottish-based construction firm Balfour Beatty as the main contractor, innovative architects Mamou-Mani as the 3D print specialists and AKTII as structural engineers. Together, they'll create an installation inspired by the hexagonal basalt columns which connect the Giant's Causeway in Northern Ireland and Fingal's Cave in Scotland's Inner Hebrides to showcase the capabilities of the geopolymer concrete material.

The team will use local materials provided by Scottish Water and local manufacturing facilities to create and site the installation, which is intended to remain a permanent iconic Glasgow landmark.

Balfour Beatty are keen to explore the potential for incorporating 3D-printed geopolymer concrete component fabrication and utilisation into their training and apprenticeship programmes, helping young site operatives, engineers, architects, construction managers and concrete technologists to expand their knowledge and skills into future materials as well as those currently being used.



Roisin Hyde's research into a more sustainable concrete examines the use of industrial waste from activities like mining and quarrying

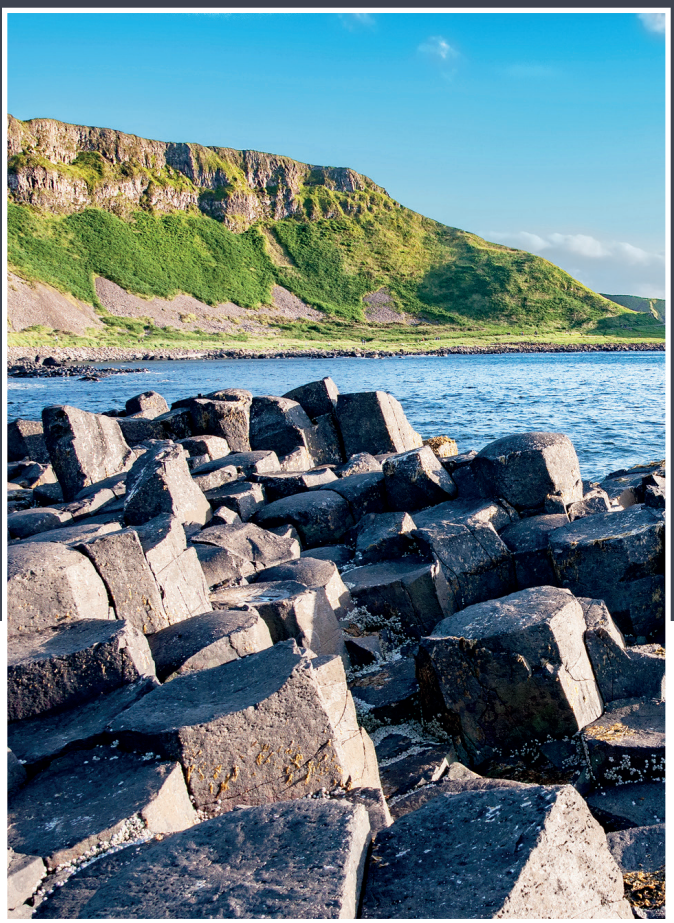
The COP26 project will be funded by Innovate UK's ICURe programme, which is helping Roisin to engage with the potential marketplace and explore business uses for her product.

INSPIRED BY LOCAL CONNECTIONS

In some ways, Scotland is the perfect place for Roisin to demonstrate her discoveries – because, she says, it's leading the world in terms of collaborative efforts to find sustainable ways of working. *"You're at least five years ahead of everybody else,"* she says.

"I've spoken to people literally all over the planet, from Alaska to Australia, and the most focused and strategic thinking I've seen has been in Scotland. I'll speak to someone at ScottishPower, and they'll put me in touch with someone at Scottish Water. When I speak to them, they have a contact at Zero Waste Scotland. They all know each other, and they're working to the same goals.

"If we're going to have a circular economy, you need to have a connected society, where industries work together to generate those relationships. I've found that Scotland has a very high level of dialogue between different actors and policymakers. So I'm not at all surprised that you're hosting COP26. Scotland is the natural place for this event to happen."



Roisin's COP26 project is inspired by the hexagonal basalt columns of the Giant's Causeway and Fingal's Cave•

GEOPOLYMER CONCRETE AT A GLANCE

- Meets **9 UN Sustainable Development Goals:**
  - **Renewable energy use**
  - **Jobs and economic growth**
  - **Innovation and infrastructure**
  - **Sustainable cities and communities**
  - **Responsible consumption**
  - **Climate action**
  - **Life below water**
  - **Life on land**
  - **Partnerships for the goals**
- Concrete can be created using up to **96% local waste materials**
- 3D printing means:
  Less **waste**
  More **accuracy**
  Simpler **production**
  Integrated **design and fabrication** process
- Conventional concrete = up to **1 tonne CO2** per tonne of product
- Compressive strengths:
  Conventional concrete: up to **40MPa**
  Geopolymer concrete: **>140MPa**

*This case study was prepared by Construction Scotland Innovation Centre on behalf of the Scottish Construction Leadership Forum – **March 2021**.*

CONSTRUCTION SCOTLAND INNOVATION CENTRE