Regenerative design for building engineering: the role of the structural engineer

Introduction
The regenerative principles outlined by Oliver Broadbent and James Norman in this issue (page 10) include understanding and responding to our social and ecological impacts across complete systems (i.e. the entire supply chain), ending our resource depletion and waste creation by moving to create an abundance of useful materials, and using our work to influence others and drive our industry to be a positive contributor to the planet. If we are to create wholly positive projects in the future, as described by the authors, then we will need to see the purpose of construction itself transform to be regenerative – it just isn’t possible to design fully regeneratively within the current system.

However, there are many things that we can do today on projects to lay the groundwork for a regenerative future. We know from history that grassroots change drives what is deemed ‘possible’ and even ‘acceptable’ by those in control of the wider political and economic systems. As such, we believe that it is important that today’s structural engineers understand what aspects of regenerative design could be applied here and now.

For the purposes of this article, we will focus on four areas:

- Designing for place
- Circularity and reuse
- Material choices
- Knowledge transfer.

We will elaborate on each of these and include some specific examples, although it should be noted that currently we lack examples that can be considered exemplars in all four areas at once.

Designing for place
As structural engineers, we are concerned with the design and specification of structural materials, but too often we remain disconnected...
from the place we are designing in or the materials we are specifying. We fail to heed Gustav Eiffel’s famous words: ‘The engineer […] should be warned that when [their] machine is put to work, it is not only a part of a mechanical, but of a social system.’

In a regenerative context, we need to understand the wider connection and impact of our design decisions along the entire supply chain – the so-called “second site” – understanding the impact on people and nature of material extraction, element manufacture, installation on site, and so on. Positive impacts could come in the form of nature restoration, pollution absorption, and helping to ensure fair wages, a political voice, and equitable education. To have a bigger say in ensuring our designs address the needs of the communities we serve – whether it’s those on site or throughout the supply chain – we must engage such communities in our processes to create vested interests in doing good. (For further discussion of this idea, see the article by Emma Crichton on page 33.)

Eladio Dieste exemplified structural innovation and designing for place by pushing the possibilities of local materials through careful use of structural form. Dieste developed his work in Uruguay, a country with limited material resources. His strong understanding of what the local workforce could achieve with local materials led him to embrace double curvature on his projects to unlock the use of reinforced and prestressed local brickwork to achieve what others thought only possible with concrete, but at a lower cost. This resulted in Dieste being hired to apply his inspiring structural forms to warehouses, bus shelters and petrol stations – buildings rarely associated with eye-catching form!

At the Ruhehe Primary School in northern Rwanda (Figure 1), MASS Design Group stretched the project brief to maximise local benefits throughout the design and construction process. The design was undertaken in collaboration with the African Design Centre, training 10 fellows in architecture and engineering in a country lacking in design professionals. The construction process was designed to maximise local labour and advance local construction skills, providing training in carpentry and masonry to 30 women, in an industry dominated by men. Safety standards (such as the use of scaffolding) were increased and embraced as MASS took time to work with the locals to help them understand the benefits. Local volcanic stone, previously seen as waste (and found in abundance lying by the roadside), was used as a structural material to form the school’s main feature walls.

In the 1980s, Walter Segal developed a method for self-build for the construction of two housing estates in London (Walter’s Way and Segal Close). The design responded to the needs of this place by minimising the use of wet trades (to aid the use of unskilled labour, and facilitate future upgrades) and was based entirely around locally available standard timber sizes to reduce waste. A decade later, the principles were replicated for the Nubia Way development, London’s first black self-build housing co-operative in Lewisham, Southeast London. The project responded directly to the needs of the local community by being set up in a way that allowed working-class tenants to buy a stake in their housing using labour in place of cash. Many of those who joined and built their own timber houses in this project ended up getting new qualifications or jobs in construction!

A grander-scale example of designing in response to place is the Arc Gymnasium in Indonesia. Here, Atelier One used arches and anticlastic gridshells to enable the use of locally sourced bamboo as the primary structural material of the gymnasium’s roof, along with local labour for the build. The project was joint winner of the Supreme Award for Structural Engineering Excellence in 2022.

**Circularity and reuse**

Retrofit projects, and those using reclaimed materials, avoid the associated generation of waste, resource depletion, and emissions. While this may sound like the ‘less harm’ associated with sustainability (as opposed to the ‘more good’ associated with regenerative design), there is clearly potential for reuse to result in zero harm, a strong foundation to enable other aspects of a project to lead to net-positive outcomes.

To achieve this, we must push beyond partial reuse and close the loop entirely. Currently, only a fraction of our profession are designing structures for genuine disassembly, and even fewer of us are designing for future disassembly while using reclaimed structural elements today, something which needs to rapidly change.
The refurbishment of existing buildings is nothing new, with many eye-catching examples around the world, such as the Argo Factory in Iran, the Zeltz Museum of Contemporary Art Africa in South Africa, and the TWA Hotel at JFK Airport in New York. The HYLO building in London joined the Arc Gymnasium in sharing the 2022 Supreme Award, for adding 13 storeys to an existing 16-storey building (Figure 2). This was enabled by structural engineers at AKT II back-analysing the existing structure and redirecting load paths to exploit existing spare structural capacity. One wonders already what the next life of HYLO will be.

There are also a growing number of engineers and designers using reclaimed elements in the place of new materials. The Kristian Augusts Gate 13 project in Norway claims to be made from 80% reused components, including concrete floor plates, gathered from 25 different demolition sites. Pad foundations at Cuerden Valley Visitor Centre in the UK are made from old tyres filled with compacted gravel, and reclaimed steel elements have been used on a variety of projects such as the ARTIS Groote Museum in Amsterdam, the Olympic Stadium in London, and several office projects featured in the March 2023 issue of The Structural Engineer*.

A number of tools have recently been developed to support the industry’s transition to circularity, such as the ASBP Steel Reuse Toolkit developed as part of the DISRUPT project (https://asbp.org.uk/toolkit/disrupt-steel-reuse), the Regenerate tool by Sheffield University (https://urbanflows.ac.uk/regenerate/), and the Arup Circular Building Toolkit (https://ce-toolkit.dhub.arup.com). The institution’s new guide Circular economy and reuse: guidance for designers brings practical guidance on material reuse to the structural engineering community.

Material choices
To ensure net-positive impacts along our materials’ journeys from source to site, we need to work more closely with our supply chains. Biogenic materials (e.g. timber, hemp, straw) sequester carbon from the atmosphere and could feasibly be manufactured into structural materials without emitting any greenhouse gases at all. They could also lead to broader net-positive outcomes if planted with this in mind – increasing local biodiversity, providing local resilience against flooding and landslides, or enhancing soil nutrients as cover crops.

Designing with reclaimed materials (e.g. deconstructed steel frames or secondary cross-laminated timber) along with abundant unprocessed materials (e.g. earth, stone) can also help avoid the emissions and pollution we associate with construction, and draw down on the levels of waste our industry (sadly) takes for granted. Perhaps one day our concretes and steels will even evolve to present similar benefits.

Identifying what is of most benefit means asking what is abundantly available – this could be an underused low-strength timber, waste rubble from nearby projects, or earth that has to be excavated to enable site access. As a starting point for new projects, we’d challenge engineers to ‘think local’ and work out from there.

The University of East Anglia Enterprise Centre (Figure 3) uses locally sourced timber taken from Thetford Forest, following discussion between engineers BDP and the local industry, which was previously using the wood for fencing. The YeMake example given by Broadbent and Norman uses trees that needed to be felled for other reasons (such as damage or disease) – making use of this wood structurally is a positive move when compared with the alternative scenarios of burning it or turning it into cardboard.

Combining biogenic materials with modern construction technologies presents further opportunities still. UK pioneers ModCell created a panelised system made up of a timber frame and straw bales, offering the benefits of modular construction, local sourcing and bio-based materials in one go. There are more than 30 examples of built structures, from houses to warehouses (www.modcell.com/projects/), and the ModCell system was used in a new-build facility, The Nucleus at Hayesfield Girls’ School (Figure 4), featured in The Structural Engineer in October 2014. A similar cassette-based system has since been developed by Natural Building Systems (https://naturalbuildingsystems.com/), using hemp-composite within a plywood and oriented strand board cassette for both walls and floors.

Knowledge transfer
A regenerative system should continue to thrive once the initial team has moved on. Knowledge transfer can play a big part in enabling this, often overlapping with the principles described earlier under Designing for place. The engineer should ask how their structure, construction methods and materials can empower those connected with the project, from the design team to the local community. This includes sharing knowledge with the global profession around how they designed regeneratively, and what lessons they learned along the way.

Finding time to run project debriefs, write up our work, and coach others (both in education and the workplace, including our ‘competitors’) should be treated as an investment in our future. This all seeks to change the system and context that we work in, enabling the global construction industry to accelerate towards a regenerative future more quickly.

Many of the projects discussed in this article ensure a more regenerative future by passing on skills and knowledge to others. The IStructE’s

“IT’S WORTH CONSIDERING NOT JUST WHAT IS WITHIN YOUR ZONE OF CONTROL, BUT WHAT YOU COULD INFLUENCE MORE BROADLY

*Treating the broader industry as competitors is clearly a barrier when we know that knowledge-sharing fosters innovation and progress.
Regenerative principles for structural engineers

Feature

Recent activities on climate change are a similar cross-industry example, as is the CROSS (Collaborative Reporting for Safer Structures; www.cross-safety.org) scheme and the way safety has improved as a result. The speed of change seen in the profession has only been possible because companies and individuals have been willing to share their knowledge so freely.

On many projects, major international consultancies are hired to work alongside (typically smaller) in-country firms, facilitating a two-way transfer of knowledge and experience. Following the 2013 Rana Plaza collapse in Bangladesh, engineers at Arup designed a methodology for carrying out structural safety assessments on garment factories across the country, and worked directly with local engineers to enable the inspection of more than 3700 factories. This kept a critical industry moving (the Bangladeshi garment industry employs a significant number of women), but more importantly, it also upskilled an industry in safe structural design.

Similarly, La Référence school in Haiti, by Eckersley O’Callaghan, prioritised collaboration and learning with local engineering and construction teams. All documentation and processes were designed to develop local understanding of structural behaviour and become educational tools for future replication.

Influence of the regenerative engineer

An issue for some engineers is the belief that many of these things are outside their zone of influence. It’s therefore worth considering not just what is within your zone of control (e.g. specification of materials for the primary structure or options for the foundations), but what you could influence more broadly (e.g. the client’s regenerative aspirations).

For a project to be regenerative, this needs to be a fundamental aspiration from the beginning. Our greatest opportunity to positively influence comes right at the start, so this could mean only working with clients who share your regenerative aspirations and refusing projects that don’t. Otherwise, it could mean initiating a conversation with the wider design team at the project’s inception, so you start on the right track. Long-term, the best opportunities come from relationships built on mutual understanding and shared values, so finding clients aligned with these values is likely to pay dividends.

Changing mindsets and working practices means embedding a culture of regenerative thinking within practices. To enable this, opportunities for everyone to input ideas and share knowledge should be created. Ensuring that junior and senior staff all have an equal say, running external workshops with local communities, and cross-industry knowledge-sharing mid-project all help others to understand how to move towards more regenerative principles and foster a culture of sharing.

Summary

If funders, developers and policy-makers are going to feel empowered to make radical changes to their policies to move towards a more regenerative future, then it is up to practising designers to show them how this could be achieved. Today’s ‘less harm’ mentality is struggling to even tackle the single problem of carbon emissions, and yet we know that this is intertwined with issues around biodiversity, social equity and safety. By being ambitious, fostering long-term relationships and sharing knowledge, we hope that we can show a glimpse of the future in each of today’s projects, and bring others along on this journey to help us to take bigger steps on the next.

REFERENCES


2) Institution of Structural Engineers (2022) ‘Structural Awards 2022: Awards special’, The Structural Engineer, 100 (11), pp. 27–54; https://doi.org/10.56330/JCTO9260


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