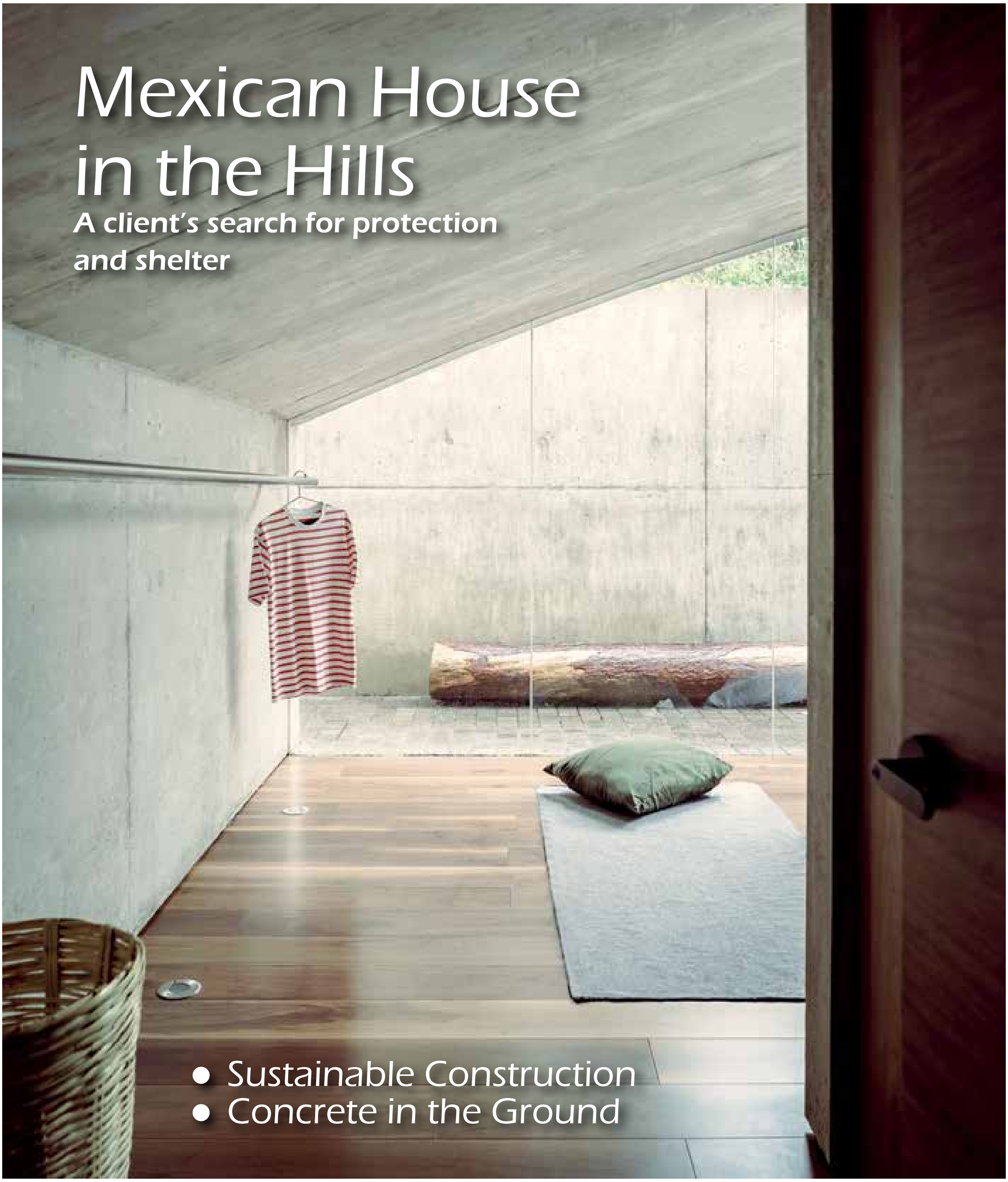
CONCRETE ENGINEERING
International

January 2022
Volume 26 Number 1



Concrete progress: making the world's most popular building material sustainable

There is no getting around it: we have a concrete problem. The most widely used building material in the world is also one of the least sustainable. Over ten billion tonnes of concrete are produced each year, making the material second only to water in global annual consumption. And, production will only continue to grow as the world urbanises, densifies, and scrambles to build the infrastructure for a net-zero future. All this comes at an enormous cost to the environment.

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The issue is not concrete *per se*, but cement. That material, the binding agent in concrete, is responsible for up to 8% of global carbon emissions alone. For each kilogramme of cement produced, nearly a kilogramme of CO_2 is released into the atmosphere.

Bleak news, to be sure, and especially so for the readers of *Concrete Engineering International*. But, there is hope. Emerging methods in concrete production and construction promise a greener, more sustainable future for the material. Concrete recycling, carbon sequestration and tools such as Autodesk EC3 that help measure, compare and minimise life-cycle carbon costs are all helping to bring the industry closer to net zero.

Concrete and embodied carbon

But why is cement so unsustainable in the first place? The answer lies in its embodied energy – the energy consumed by the processes associated with producing a material, from mining and processing natural resources to manufacturing, transport and product delivery.

Although cement makes up only 10% of the concrete, it is responsible for 80–90% of concrete's embodied carbon. That is because producing cement requires heating a mixture of limestone, silica, alumina and gypsum to 1300–1450°C. Making all that heat burns a tremendous amount of fossil fuels and the chemical reaction that forms concrete itself generates even more CO_2.

This means that reducing the amount of cement in the concrete – or finding less carbon-intensive ways of making cement – can significantly lower its embodied energy and carbon cost.

'Green' concretes

In place of cement, engineers have been specifying fly ash as a binder since the mid-1990s. As fly ash is finer than Portland cement, it can fill smaller voids than cement particles. This makes a stronger, less permeable concrete that requires less water to make it workable, maximising strength while maintaining constructability. Fly ash can replace up to 35% of the cement content (some codes allow more), translating to sizable cost and carbon savings. Using fly ash, though, does require some advanced planning. The material sets and strengthens slightly more slowly than traditional concrete, which the construction schedule should reflect.

Similarly, GGBS can be used in a concrete and is finer and cheaper than standard Portland cement. It typically substitutes 50% of the cement content, although it can be up to 80%, meaning significant savings in both cost and carbon emissions. GGBS will produce a mix whiter, and often stronger, than traditional concrete in the long term – but because its initial strength is lower, it is unsuited to emergency or repair work.

Another option is using Portland limestone cement – also called general-use limestone cement. In this mix, limestone substitutes a portion of the cement, saving up to 10% in CO_2.

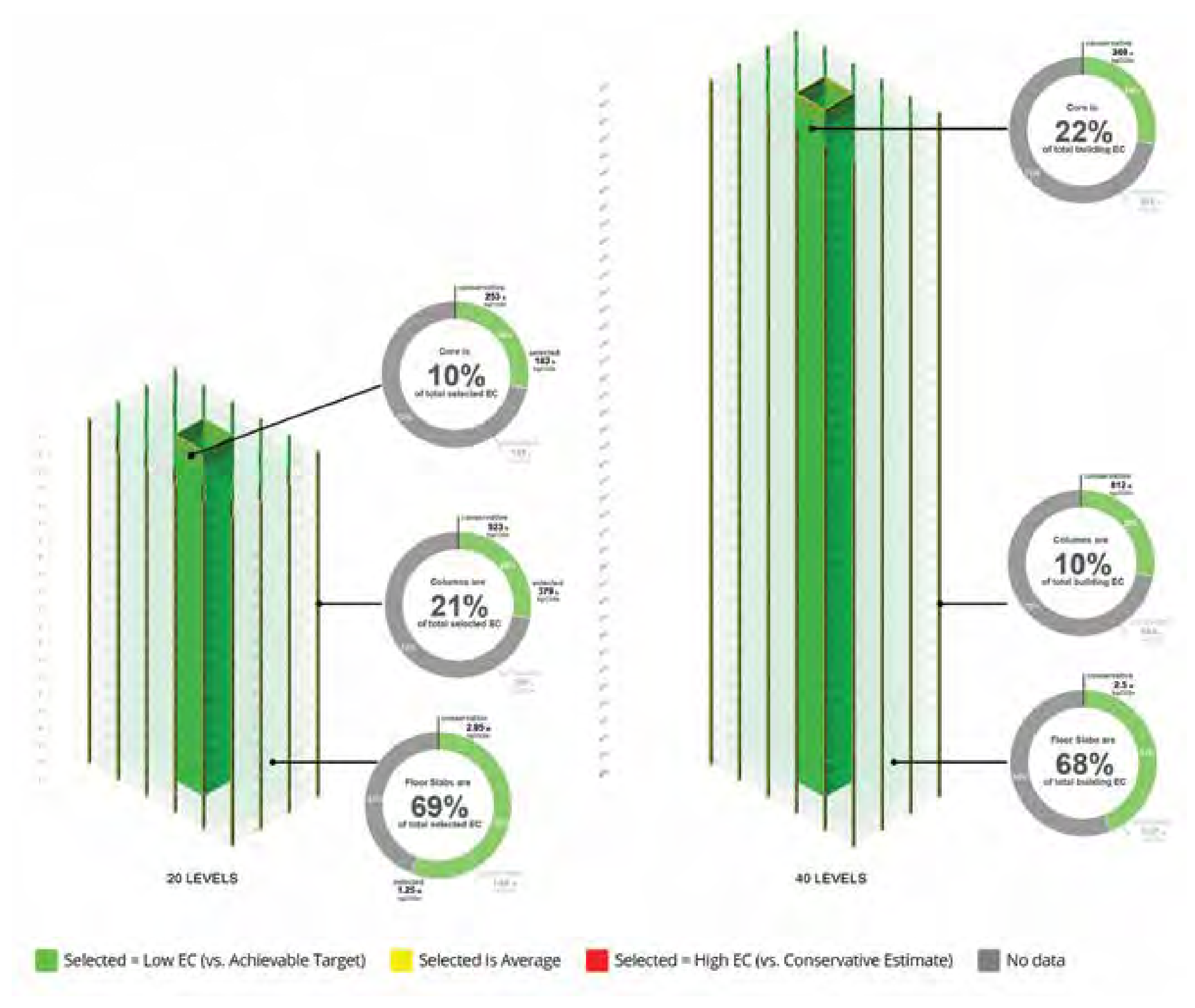
Recycling concrete

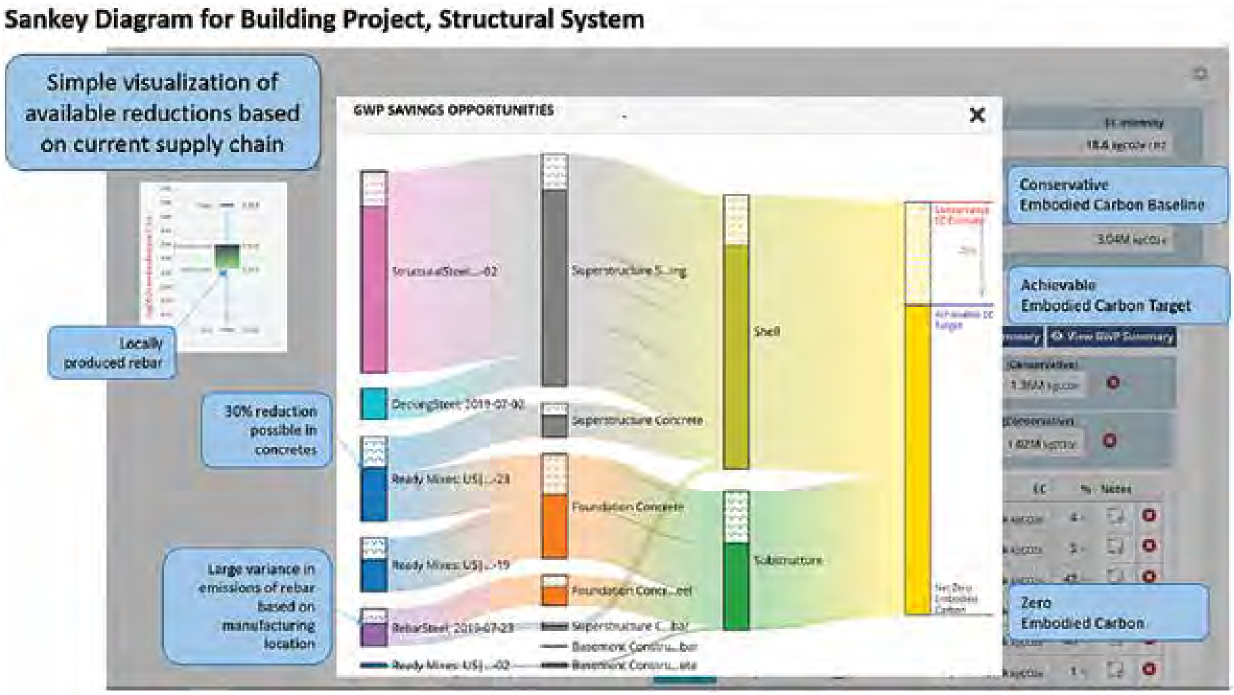
Concrete recycling is becoming an increasingly popular way of reducing the embodied energy cost of building new. After a structure has served its original purpose, its concrete can be crushed and recycled into aggregate for use in new concrete, as backfill, below slab on grades, or as road base.

Recycled concrete can come from old structures, sidewalks, building slabs, foundations, curbs and more. Typically, concrete without heavy reinforcement is most suited to recycling. Existing concrete structures are demolished and transported to a facility where a secondary impactor processes the broken-up concrete. Then, a screen filters out dirt and other foreign objects, and the concrete is separated by size.

Recently, architects have championed this process to create signature new buildings around the world. David Chipperfield Architects and structural engineer IGB Ingenieurgruppe Bauen, for example, used 95% recycled concrete for the Kunsthaus Zurich. Their design makes the most of the concrete's brighter, whiter colour as a design feature lending the building a pearlescent quality. In part because of the success of this building, the material is gaining popularity as an option for projects across Europe and throughout the United States.

Visualising embodied carbon (EC) in concrete buildings using Environmental Protection Declarations (EPDs).





Visualising potential savings.

Carbon sequestering

Beyond these methods, carbon sequestration is emerging as a promising technology to reduce concrete's embodied energy. The process introduces recycled CO_2 into fresh concrete, converting the gas into a mineral that remains in the concrete. The environmental advantages of carbon sequestration are two-fold. First, the mineralised CO_2 strengthens the concrete, reducing the total amount of cement by up to 10%. Second, the process diverts CO_2 that would otherwise enter the atmosphere. Companies such as CarbonCure are putting the technology to use, using existing concrete batching plants retrofitted with equipment that injects the CO_2 into a hopper or central mixer.

Minimising life-cycle costs

A building's structure accounts for the vast majority of its embodied energy and engineers designing concrete structures must negotiate priorities that, at times, conflict. The drive to reduce the material cost, embodied energy and environmental impact of a building, for example, can mean shorter lifespans or less flexibility for reuse.

Strategies such as using post-tensioned slabs, hollowcore slabs, or bubble-deck systems help reduce the total amount of concrete in a structure; a short-term win. But, in this case, penny wise is pound foolish. These systems can make for inflexible framing systems that are difficult to adapt to new use, making the building more likely to be replaced with a new one down the line. Consider that even an energy-efficient new building will take 65 years to save the same amount of energy as a repurposed project and the cost of inflexible design becomes clear.

The most sustainable way to build is to reuse. It is up to architects and engineers to design for future flexibility, to ensure new buildings can be adapted. Techniques with small upfront material and energy costs can pay dividends down the line, like incorporating longer column spaces or greater live-load capacities than required. Futureproof designs with flexible structural systems are especially important for long-lifespan projects, such as academic and institutional buildings or transportation infrastructure.

Now, new software such as Autodesk EC3 is helping designers and engineers make informed design decisions to reduce life-cycle carbon costs. EC3, currently in public beta testing, integrates directly with BIM 360 to analyse and present the embodied energy of building materials. The tool is powered by data about the life-cycle environmental impact of materials from Environmental Product Declarations – an international programme that collects and databases this information. Materials quantity data can be imported directly from BIM into EC3 to create a heat map that visualises the project's embodied carbon footprint. The software empowers designers to compare life-cycle costs of different structural systems or a single material sourced from different plants.

Towards a sustainable future

To bring about a carbon-neutral future – and here we have no choice – we must begin using concrete more sustainably. Although we do not have a magic bullet solution, this is more possible today than ever before. By understanding and advocating for solutions such as low-carbon mixes, recycled concrete, carbon sequestration and embodied-energy-conscious design – and dedicating ourselves to searching for even more sustainable methods – we can begin building a greener concrete future. ■