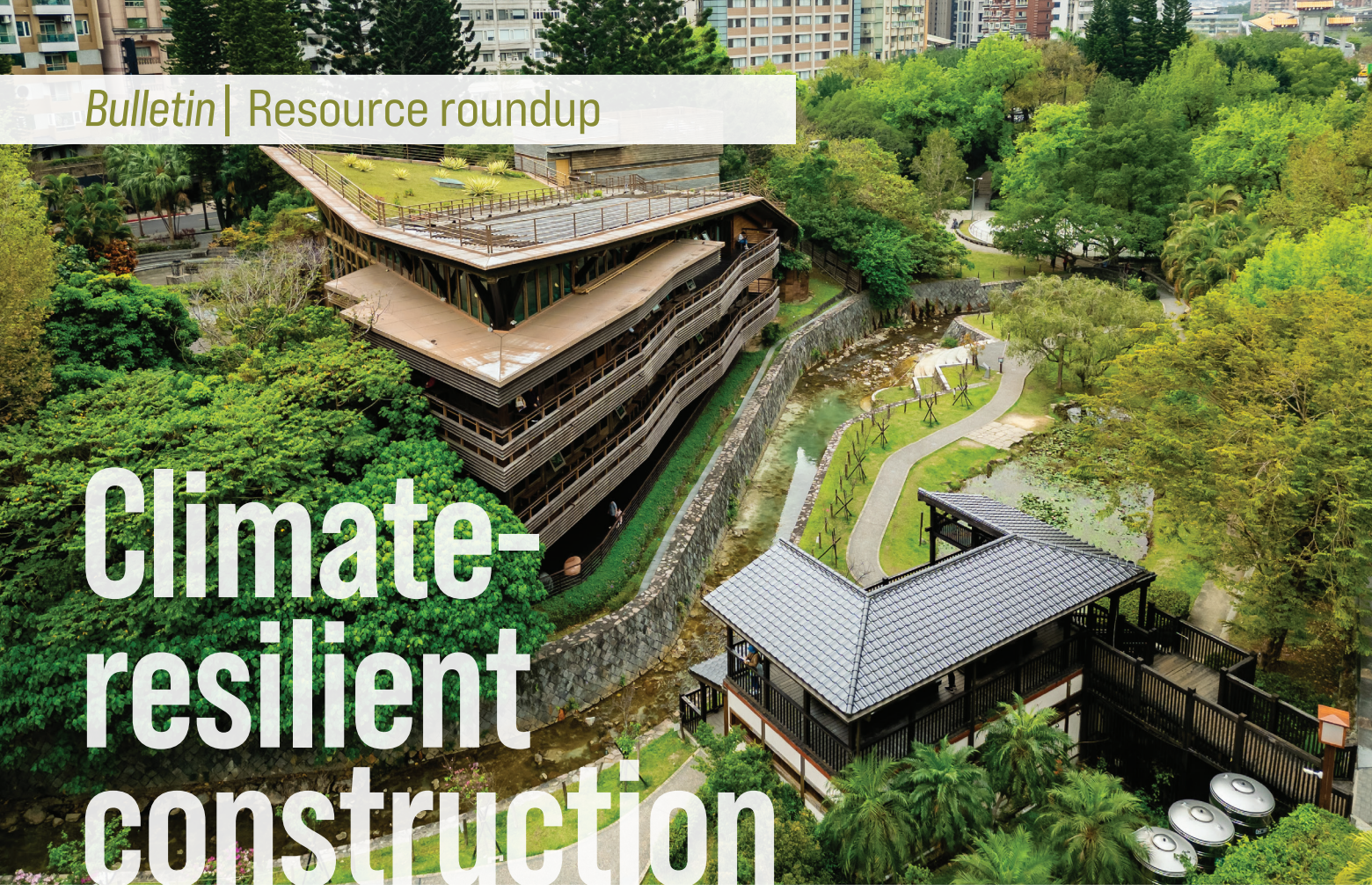

Climate-resilient construction

What material innovations and evolving standards are making possible

By Randy B. Hecht

Sustainability and circularity did not used to be priorities in construction. But starting with the introduction of ecological architecture in the 1960s and the energy crisis in the 1970s, the concept of sustainable development took hold and now guides many national building standards around the world.

Recent materials science advances and innovations are creating new opportunities to reduce construction companies' carbon footprint and promote more environmentally friendly design and building practices. For example, "companies are starting to use recycled materials in their buildings. This [practice] helps reduce the environmental impact of construction and can also save businesses money," note co-authors Julia L. Freer Goldstein and Paul Foulkes-Arrelano in their book, *Materials and Sustainability: Building a Circular Future* (Routledge, 2024).

The authors add that environmental impact lies not only in the materials used but also in "how the products are manufactured and how they are handled at the end of their useful life. No discussion of efficient manufacturing would be complete without addressing the entire life cycle of materials."

As a result, green advocates are watching not just which materials are being used in construction but also how manufacturers operate their facilities—from the chosen energy sources to waste management practices. This heightened awareness of operations supports the transition to a circular economy.

Another emerging and increasingly relevant trend in the construction industry involves integrating climate resiliency strategies into building design and construction. While the advances mentioned above aim to manage the construction industry's impact on the environment, others seek to manage climate events' impact on buildings. That has given rise to the term "building resiliency," which refers to a building's ability to function as temperatures reach new extremes, sea levels rise, and fierce weather events and wildfires become more commonplace.

The Whole Building Design Guide, a project of the National Institute of Building Standards, cautions on its web-

site: "As the built environment faces the impending effects of global climate change, building owners, designers, and builders must design facilities to optimize building resiliency." (https://www.wbdg.org/do/sustainable)

As nature changes, so too must building standards, materials, and designs. Numerous research and development projects—some still in the lab, others already on the market—will help make the necessary changes a tangible reality.

MATERIAL INNOVATIONS

Net-zero and carbon-trapping concrete

Cement and concrete are the literal foundation of the construction industry, but these materials also contribute substantially to global carbon emissions. Many research groups are working to develop alternatives to traditional Portland cement, including companies started by ACerS Fellows Richard Riman (Solidia Technologies) and Yet-Ming Chiang (Sublime Systems). Two other recent developments in this area are described below.

Fortera: A mix maverick on the market

San Jose, Calif.-based Fortera is "a five-year-old company that's effectively 18 years in the making," says co-founder and CEO Ryan Gilliam, a climate tech serial entrepreneur with a Ph.D. in materials engineering.

Its low- to zero-CO_2 cementitious product, ReAct, is a "reactive calcium carbonate polymorph, known as vaterite, which can be blended into ASTM C150, C595, or C1157 cements or mixed into concrete during batching." The solution has its origin in an earlier venture, Calera, which mimicked the way coral reefs and shells form in nature to develop a new type of cement that captures CO_2.

Calera was awarded more than 100 patents, but "the technology just wasn't grounded in economics," Gilliam says. In 2019, he revisited the technology from a fresh perspective: Instead of competing with cement companies, he could collaborate with them and integrate the product with their existing materials via their existing feed stocks, "from quarry to kiln."

"That allowed us to drive down the cost to make a product that's economically competitive, even without a green premium," Gilliam says. "Reducing capital costs, reducing operating costs, getting to large scale matters more than anything if you're going to have a meaningful impact."

To that end, Fortera plants use standard tanks and other off-the-shelf equipment rather than anything proprietary that could complicate the adoption process.

"When these plants are making a million tons a year of cement, and they've already paid their capital costs, the last thing they want to do is shut down to make modifications," Gilliam says.

Product data and documentation are available on the Fortera website at https://forteraglobal.com/react-product/#productdataanddocumentation.

Making waves with carbon-trapping concrete

Rather than simply reducing carbon emissions, can existing emissions be trapped in concrete and turned into new building materials? This concept is what Alessandro Rotta Loria, Louis Berger Associate Professor of Civil and Environmental Engineering at Northwestern University's McCormick School of Engineering, is working on.

The genesis of his idea is not new: Minerals such as calcium carbonate and magnesium hydroxide can form when an electrical current is applied to sea water. In theory, this process could be used to manufacture structures in sea water. However, the speed of production is inadequate for industrial purposes.

Rotta Loria imagined taking things a step further: "Can we use external CO_2 to boost the process? And the answer is yes. The process we have developed consists of applying an electrical current to sea water, and at the same time to inject CO_2 gas, which can be sequestered at an earlier stage."

This approach makes it possible to convert the gas to mineral form and accelerate the mineralization process that occurs in sea water. Next, his team puts the resulting magnesium hydroxide in contact with the water so it can react and be converted to forms of magnesium carbonate that act as carbon sinks.

The biggest challenge in the process was "developing the knowledge that allows us to fully control the process," Rotta Loria says, which is "sensitive to variables such as the flow rate of the CO_2 that is injected, the magnitude of the electric stimulation applied, or the flow rate of the water that is present in the reactors."

As with all R&D breakthroughs, another challenge is making the project commercially viable. Rotta Loria's team is working with San Pedro Garza García, Mexico-based building materials company Cemex, which is sponsoring the research, to "upscale the process and hopefully bring it to market."

Another approach to sequestering carbon in building materials, developed by ACerS member Brian Gorman, is described in the September 2024 issue of the *ACerS Bulletin*.

Material innovations beyond concrete

While cement and concrete are major focuses for sustainability research in the construction industry, all aspects of construction can benefit from novel material formulations and designs. Some of the most cutting-edge advancements are recognized each year by North American media company Green Builder Media through its annual Sustainable Products of the Year list.

One of this year's winning products is ACRE, "a sustainable, versatile building material made from upcycled rice hulls" that manufacturer Modern Mill offers as a substitute for wood. The company says ACRE "can be easily cut, routed, sanded, and customized with regular woodworking tools." Furthermore, "The material is also easy on blades and has minimal melting or static." (https://bit.ly/Building-with-ACRE)

Another winning product, introduced by manufacturer ClarkDietrich, is "a new line of low embodied carbon (LEC) steel framing products," including a metal drywall framing system, structural steel, and floor framing that the company says allows for "greater freedom in designing sustainable buildings." (https://bit.ly/LEC-steel-framing)

View the full list of Green Builder's 2025 Sustainable Products of the Year at https://www.greenbuildermedia.com/blog/2025-sustainable-products-of-the-year.

Green roofs are not a new idea, but they are attracting renewed interest as a means of cooling buildings and their surrounding environments—and contributing to climate resiliency. But getting those results involves more than landscaping roofs and letting nature take its course. In the two-part series "Ensuring green roofs deliver" (https://bit.ly/4lDiIeL) and "Mistakes and misconceptions surrounding green roofs" (https://bit.ly/4il9a5q), FacilitiesNet reviews the decisions that determine whether green roofs will perform as intended.

BOOKS FOR A DEEPER DIVE

Recent years have seen numerous books published on the topic of sustainable construction. Below are some of the new books on this topic publishing in 2025.

3D Concrete Printing: State of the Art and Applications

Publish date: January 2025

Publisher: Wiley–ISTE

Description: Discusses issues relating to concrete materials, overviews current printing processes, and describes the mechanical behavior of printed structures.

Development and the Sustainable City: The Limits of a Technical Approach

Publish date: January 2025

Publisher: Wiley–ISTE

Description: Examines rapid growth in cities, as well as the sustainability issues it poses, in several ways.

Advances in Bio-Based Materials for Construction and Energy Efficiency

Publish date: February 2025

Publisher: Elsevier

Description: Discusses bio-based materials and biotechnologies for infrastructure application, building energy efficiency, and pollution treatment.

Climate Resilient Construction and Building Materials

Publish date: April 2025

Publisher: Cambridge Scholars Publishing

Description: Integrates several research papers on climate resilient building techniques and materials.

Advances in Sustainable Concrete for Construction

Publish date: June 2025

Publisher: Springer

Description: Explains sustainability of concrete in the context of current extraction, formulation, and use scenarios.

Sustainable Construction Management: Research and Practice Companion

Publish date: June 2025

Publisher: Springer

Description: Presents sustainable construction management strategies, practices, methods, and procedures. ■

EVOLVING STANDARDS

Overview of green building rating and certification systems

Numerous frameworks exist to rate the sustainability of buildings, each with their own pros and cons. One entity that helps keep track of them all is the National Institute of Building Sciences (NIBS).

Established by the U.S. Congress, NIBS is authorized "to conduct research, establish performance criteria, promote standards adoption, and accelerate collaboration between public and private stakeholders to advance transformational technologies in the built environment."

Its projects include the Whole Building Design Guide (https://www.wbdg.org), which maintains the Federal Facility Criteria, an electronic library containing more than 6,000 documents "direct from participating federal agencies," including "construction guide specifications, manuals, standards and many other essential criteria." Its resources also include a tools page that provides brief descriptions of and links to desktop and web-based estimation, calculation, assessment, and tracking tools used in the building industry (https://www.wbdg.org/ar/tools).

In addition, the website offers an extensive review webpage called Green Building Standards and Certification Systems, which includes a discussion of emerging trends; an explanation of the differences between prescriptive, performance, and outcome-based green codes; and a resource guide. There is also an explanation of how green building rating and certification systems work and a chart that compares systems commonly used in the U.S. market, including

- **BREEAM: Building Research Establishment Environmental Assessment Method** (https://breeam.com/breeam-usa)
- **LEED: Leadership in Energy and Environmental Design** (https://www.usgbc.org/leed)
- **Green Globes** (https://thegbi.org/greenglobes/why-green-globes)
- **Living Building Challenge** (https://living-future.org/lbc)
- **Phius: Passive House Institute US** (https://www.phius.org)
- **SITES** (https://www.sustainablesites.org)
- **WELL Building Standard** (https://www.wellcertified.com/certification/v2)
- **Fitwel** (https://www.fitwel.org)

A second chart covers international systems used in places such as Singapore (https://bit.ly/4cJByNy), Hong Kong (https://www.beamsociety.org.hk/en), Japan (https://bit.ly/440qOI7), the Middle East and North Africa (https://gsas.gord.qa), South Africa (https://bit.ly/3EfdHbL), and the United Arab Emirates (https://bit.ly/4iGbLXX). The chart also describes EDGE (https://edgebuildings.com), which was adopted by the International Finance Corporation, a member of the World Bank Group.

LEED v5 is ratified

As climate change unleashes more frequent and more damaging natural disasters, green building standards must evolve to remain relevant. A 2023 investigation by Politico's *E&E News* and the nonprofit First Street Foundation, which models likely climate impacts, found that 800 LEED-certified buildings constructed in the preceding decade were "at extreme risk of flooding." (https://bit.ly/4cDLJmp)

That September, the U.S. Green Building Council began drafting the standards that would become LEED v5 (https://www.usgbc.org/leed/v5). Its website notes that the new certification was developed to "champion solutions to align the built environment with critical imperatives including decarbonization, quality of life, and ecological conservation and restoration. LEED v5 will drive real-world impact and positive change." Following two rounds of public comment in 2024, LEED v5 was ratified in March 2025.

The Council presents the new framework on its website as "designed to drive the market towards a near-zero carbon reality that is equitable, resilient, and promotes the wise, safe use of all resources." It provides these definitions of its three core areas of impact:

- **Decarbonization** refers to targeted "reductions in operational, embodied, refrigerants, and transportation emissions."
- **Quality of life** encompasses "improving health, well-being, resilience, and equity for building occupants and their communities, making spaces not just environmentally friendly but also people friendly."
- **Ecological conservation and restoration** emphasizes "strategies that limit environmental degradation and contribute to the restoration of ecosystems, ensuring that our built environment exists harmoniously with nature."

According to its LEED v5 FAQ (https://bit.ly/3Y2bB5B), "there will likely be some period of overlap when it is possible to register for either LEED v4/4.1 or LEED v5." Projects registered under v4 and 4.1 will be given the opportunity to upgrade to v5.

PDFs of the LEED v5 frameworks for Building Design and Construction, Building Interior and Construction, and Building Operations and Maintenance are available for download at https://www.usgbc.org/leed/v5.

About the author

Randy B. Hecht is founder and owner of Aphra Communications (Brooklyn, N.Y.). She works extensively with clients in Europe, Asia, and the Americas on materials science content produced for global audiences. She has written The American Ceramic Society's annual report on international ceramics and glass markets since 2009. Contact Hecht at rbhecht@aphra.com. ■

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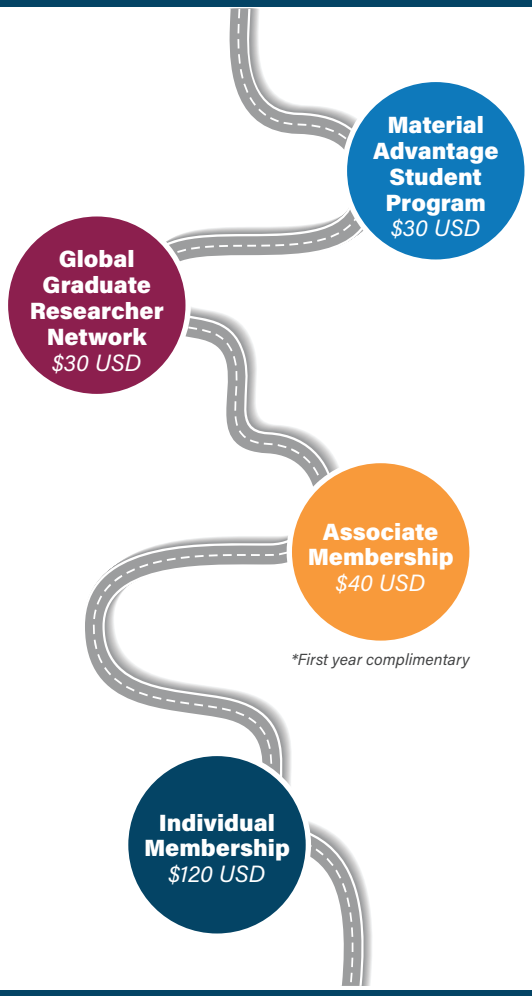

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