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Off-Piste

3DCP Cable-Car in Czech Republic

Sustainable/ Low-Carbon Construction

Formwork & Falsework

Nor any drop to spare

Water scarcity is no longer a distant concern but a rapidly escalating global crisis. Regions that were once water-secure are now struggling to meet even basic needs, threatening the foundations of food security and public health. Water is essential for life and critical for mixing, placing and curing concrete. Elevating water resource management as a key design and construction objective offers a pathway to resolving the tension between carbon reduction and water conservation. Projects such as Kendrick Elementary School in Waco, Texas – an area facing real water shortages – provide valuable insight and leadership to inform approaches elsewhere.

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Architects, engineers, contractors and specifiers are being encouraged to use low-carbon concrete alternatives that have more variability than traditional Portland cement mixes. Many low-carbon concretes require more water in the mix to remain workable, which can compromise strength, amplify volumetric instabilities, promote shrinkage cracks and crazing, and shorten the concrete's service life.

The shift toward using record volumes of Portland limestone cement (Type 1L or PLC) and supplementary cementitious materials (SCMs) – such as fly ash, GGBS, calcined clays and injected CO_2-based additives – has fundamentally changed how concrete behaves. These materials can react differently to Portland cement, influencing water demand for hydration and flowability, or impacting particle packing efficiency – if not optimised, they may require more water to fill voids and maintain consistence.

Unfortunately, many in the architecture, engineering and construction community have not updated their approaches to design, documentation, training or on-site execution. As a result, there is a tendency to treat new low-carbon concrete as if it were traditional concrete. The consequences include unnecessarily extended schedules due to delayed strength gain, reduced durability, additional mitigation measures, contractor dissatisfaction with consistence, low compressive breaks, increased risk for all stakeholders and – perhaps most ironically – the potential for higher global warming potential (GWP) due to shorter life cycles.

Using nano-enhanced concrete (NEC) with locally sourced



(Photo: Structures PE LLP, Bennett Build and O'Connell Robertson.)

Below: A bird's-eye view of Kendrick Elementary, constructed using a lower-carbon, water-conserving concrete and delivered nearly four months faster than with traditional concrete.

Right: In collaboration with Bennett Build and Tao Group, the design and construction teams at Kendrick Elementary updated project documentation and received on-site training to conserve water, reduce embodied carbon in concrete and deliver refined concrete finishes.



(Photo: Langerman Engineering, Waco ISD.)

(Photo: Bennett Build.)



Above: A refined concrete floor within a Kendrick classroom. While refined concrete shares visual similarities with sealed or polished concrete, it represents a distinct construction outcome. Refinement with NEC stabilises and restructures the concrete surface by re-integrating the material itself, forming a denser, monolithic upper layer with enhanced strength and durability, rather than relying on topical sealers or resinous coatings. The result is a harder, more durable and more sustainable flooring system[13].

materials offers an opportunity to conserve water through lower water:cement (w/c) ratios, while simultaneously improving strength, reducing porosity and extending the material's life cycle.

Understanding SCMs

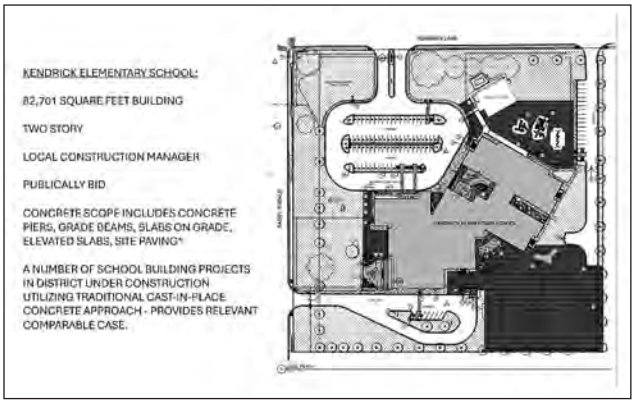
Each SCM affects concrete differently. Fly ash, for example, may reduce early strength gain and require less water for consistence. Slag cement may delay set times. Other additives, including glass pozzolan or carbon-injected solutions, can increase complexity in early hydration stages.

These differences matter. A lack of understanding – on SCMs and Portland cement – often leads to adding excess water in the field, at the batching plant, in transit or during placement. This additional water raises the w/c ratio, often weakening the concrete matrix and increasing permeability, shrinkage and surface cracking.

Eric Traffie, a certified contractor and member of Bomanite New England, the American Concrete Institute (ACI) and the National Concrete Refinement Institute (NCRI), says, "Sure, adding water is easy – but if you're not careful with how much, it can come back to bite you. Too much water might make the pour go smoother, but it can weaken the concrete long-term and lead to expensive fixes before the building even opens."

Sidonie Immler, a partner at Foster + Partners, says,

(Figure: O'Connell Robertson, Waco ISD.)



"Sustainable developments need to be looked at holistically. Solutions do not exist in isolation. Whole-systems thinking must include water management, particularly in the concrete industry."

PLC in practice

PLC, now the leading type of cement available in the USA and Canada, contains 5–15% limestone – compared with a maximum of 5% in Type I and Type I/II cements. If substituted pound for pound, this can reduce CO_2 emissions by 10–15%. While some industry participants have claimed minimal performance differences, the reality on job sites has proven more complicated. Contractor complaints persist regarding reduced finishability ('stickier mixes'), shorter set times and batch variability, and all too often, the short-term solution is simply adding more water.

Concrete is sensitive to small changes. While properly deployed PLC can improve particle packing, it can also alter hydration rates, reduce early strength and increase surface porosity. Concrete suppliers frequently increase PLC content within their mixes by 5–10% to achieve comparable cement content with that experienced in Type I and Type I/II cement mixes. While avoiding the risk of low-strength breaks, they are negating the carbon reduction benefits promised by advocates of Type 1L cement. The question remains whether the industry is truly reducing its carbon footprint while maintaining concrete quality, or merely trading one performance challenge for another.

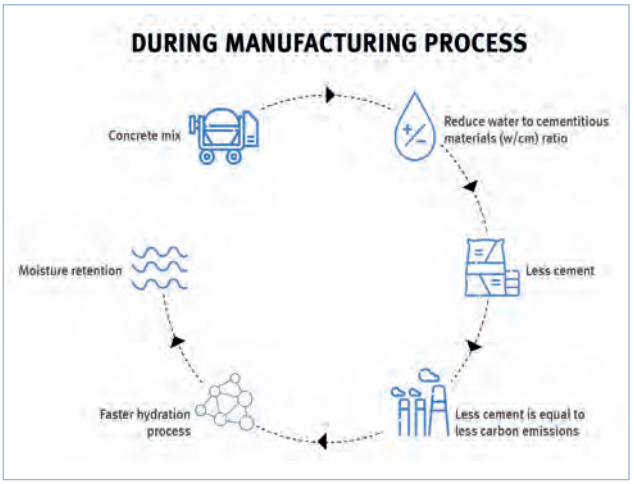
Below: The use of nano-enhanced concrete (NEC) with locally sourced materials enables water conservation through lower water-to-cementitious materials (w/c) ratios, while simultaneously improving strength, reducing porosity and extending service life.

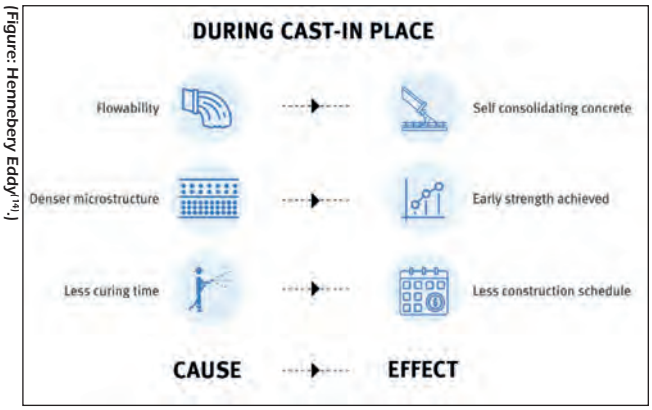
(Photo: O'Connell Robertson.)



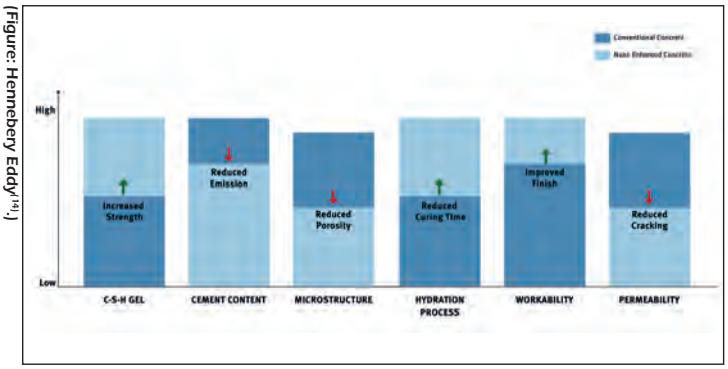
To mitigate dependence on fluctuating SCM availability and associated cost volatility, the 430-lb cement mix was designed without fly ash. A single mix design was used for both site and building concrete, further simplifying construction logistics and execution.

(Figure: Hennebery Eddy[14].)





(Figure: Hennebery Eddy[16].)



(Figure: Hennebery Eddy[16].)

Goldilocks zone: optimal hydration

Concrete needs water to hydrate cement, but too much water weakens performance. Getting the w/c ratio 'just right' is essential for strong, durable concrete. The ACI and Canadian Standards Association (CSA A23.1[1]) recommend keeping w/c ratios below 0.50–0.55 for most applications. For dense or high-performance concrete (HPC) – such as industrial slabs, watertight structures, or exterior paving exposed to freeze–thaw cycles and de-icing salts – the ratio is often limited to 0.40 or less. According to Abram's Law, higher w/c ratios reduce strength and increase porosity, shortening service life. In aggressive environments such as seawater or sulfate exposure, a w/c ratio of 0.40–0.45 is commonly specified.

Excessive water leads to:

- reduced strength (ACI 211.1[2])
- increased cracking and shrinkage (ACI 224R[3])
- segregation and bleeding (ACI 302.1R[4])
- lower freeze–thaw and chemical resistance (ACI 318[5]).

Forces shaping water use in concrete

Finding the 'Goldilocks zone' for water content is crucial for concrete performance and achieving the right economic balance in water valuation is equally essential for sustainable construction practices. According to the World Resources Institute, water prices in most regions significantly undervalue this vital resource, typically covering less than half the true cost of water infrastructure and environmental externalities.

Building Standards have established more stringent w/c ratio limitations to counter these economic systems that artificially favour water-intensive concrete solutions. These technical requirements function as regulatory safeguards against excessive water use while incentivising concrete formulations with superior durability.

Nano-enhanced concrete uses tiny particles such as nano-alumina, nano-clay, nano-platelets, nano-silica and carbon nanotubes. These particles improve cement hydration by increasing the surface area for reactions, enhancing hydrolysis throughout the matrix, reducing the number of pores created and reducing mix friction between particles. This leads to increased consistence, reduced water demand and stronger, more durable concrete. NECs can be deployed in conjunction with or without traditional low-carbon mix designs.

International Standards

Across the globe, major Codes and Standards consistently emphasise the need to limit w/c ratios to improve strength, durability and sustainability:

- ASTM C94[6] / ACI 318 (USA) – Require low w/c ratio for strength and long-term durability.
- EN 206[7] (Europe) – Sets maximum w/c ratios for various exposure classes, including carbonation and chloride resistance.
- IS 456[8] (India) – Recommends maximum w/c ≤0.50 in aggressive environments.
- AS 1379[9] / AS 3600[10] (Australia) – Prescribe w/c ratio limits for sulfate, marine and freeze–thaw exposures.
- DIN 1045-2[11] (Germany) – Emphasises impermeability by specifying low w/c ratios.
- JIS A 5308[12] (Japan) – Specifies limits on w/c ratios according to exposure and durability requirements.

Kendrick Elementary lowered embodied carbon and conserved water with a single mix design for all site and building concrete. The w/c ratios were kept between 0.36 and 0.38 while the amount of cement dropped from the regional baseline of ≥255kg of cement to 195kg.

Water-wise solutions

Waco, Texas, is quickly becoming a model for sustainable, water-wise concrete. After seasonal fly ash shortages forced the district to use all-cement concretes at the recently completed high school, Gloria Barrera, chief of facilities and operations for the Waco Independent School District, and its designer, O'Connell Robertson, were determined to find a better solution for the next new-build, Kendrick Elementary School.

Below: Water-to-cementitious material (w/c) ratios were maintained between 0.36 and 0.38, while cement content was reduced from the regional baseline of approximately 255kg (560lb) to 195kg (430lb).



(Photo: Langerman Engineering, Waco ISD.)

Engaging a concrete consultant, the design team explored new options and gravitated toward NEC technologies as a solution to their challenges. Following extensive research and early design-phase planning, the team implemented: a single NEC mix design for all site and building concrete; updated specifications; provided for additional testing to ensure accountability and peace of mind; offered training for the local subcontractor and supplier communities; and established an economical, sustainable maintenance plan that included a path for the district to eliminate future needs for stripping and reinstallation of high GWP clear coats and sealers on their interior concrete floors.

This resulted in:

- 24% cement reduction without the use of SCMs
- 32% reduction in water use
- one mix design for all sites and building concrete
- high early strength in days, not months
- avoided fly ash dependency
- fewer subcontractor mobilisations
- accelerated schedule and early building occupancy
- use of NEC concrete systems for a more stable mix
- reduced shrinkage, crazing and surface cracking
- safer floors through testing and concrete refinement
- elimination of resinous materials on the walking surfaces
- reduced overall installation and facility maintenance costs to the owner.

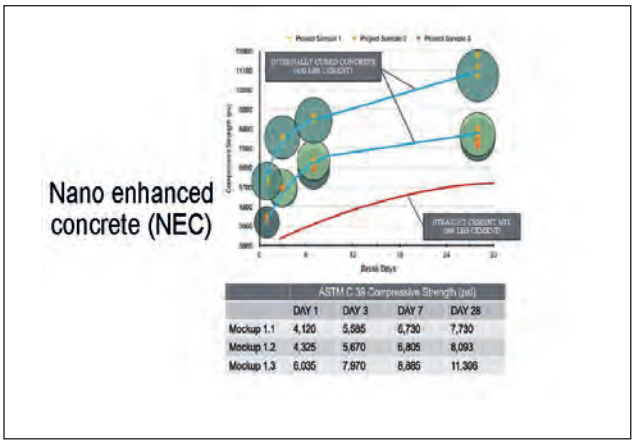
Water saving was a surprising metric – not originally on the team's priority list. Traditional 21MPa and 28MPa concretes typically use w/c ratios between 0.45 and 0.55. This is significantly higher than the w/c ratios targeted by ACI Committee 211 for durable HPC. It could be argued that the excess water in traditional mixes, while aiding consistence, is the root cause of nearly all common concrete issues, including surface cracking, curling, crazing, shrinkage and high permeability.

The core principle is simple: less water equals better concrete – as long as the cement particles are properly hydrated. Reducing water content to HPC levels has historically presented challenges with consistence and finishability. This is where NEC admixtures and additional training added value to the project. The chemical admixture alters the hydration process, allowing cement particles to hydrate efficiently. The result is a water-wise concrete with strength and durability comparable to high-performance blends – but with improved predictability and shorter schedules.

Teams at Kendrick Elementary in Waco are being trained to conserve water, reduce embodied carbon in concrete and produce refined finishes.

Fortunately, the curing properties of the NEC admixture also greatly reduce water evaporation at the surface, locking moisture into the mix so cement particles have a readily available water source throughout the curing process. The nano-enhanced concrete reduced the w/c ratio from 0.45 to between 0.36 and 0.40. As a result, the Kendrick Elementary project saved approximately 310,400 litres of water and prevented an estimated 422 tonnes of CO_2e emissions.

"The Kendrick project was an adventure worth the effort," says Gloria Barrera. "Waco ISD was ready to step up to the challenge to control costs, improve quality and reduce embodied carbon and water use. Our concrete is beautiful and far surpasses previous traditional approaches."



(Photo: Bennett Build, Langerman Engineering, Structures, Waco ISD.)

Above: Strength characteristics can be adjusted through the use of nano-enhanced concrete.

Together, Waco ISD, O'Connell Robertson, Bennett Build, Built Wright, BWC Education, Langerman Engineering, Miller Sierra, One Source, , Structures PE and Tao Group Solutions reduced cement, schedule and water – a collaborative commitment to sustainable, beautiful concrete construction.

Historically, cement reduction has been the main driver of sustainable concrete solutions. Yet, with escalating populations, ever-increasing concrete production and failing concrete, water savings will emerge as a dominant sustainability concern in water-stressed regions. ■

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