From Concrete Technology to Infrastructure Sustainability

By

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It is now generally acknowledged that global warming is here and that a world energy crisis is looming. It is also well known that civil infrastructure is responsible for a disproportionate share of CO2 and energy footprints among human activities. Is there a role for modern concrete technology in tackling these unprecedented global warming and energy crisis challenges faced by humankind?

To put things into perspective, concrete is the most used engineered material in the world today, over 12 billion tonnes annually, or 2 tonnes per year per person living on this planet. This speaks for the success of concrete as a preferred construction material. However, the production of Portland cement used in most concrete is responsible for about 5% of anthropogenic CO2 emission. Coupled to this is the fact that concrete production has an energy intensity ten times that of the general economy. This by itself should be of great concern. The problem is compounded by the fact that concrete infrastructure, particularly transportation infrastructure, requires repeated maintenance over its lifetime. This combination of material embodied energy and carbon footprint and infrastructure deterioration deserves the serious attention of all civil engineers. The construction of the built environment is unquestionably a necessity for a high quality of life. How then can we reduce the burden on the natural environment as we continue to build? In short, what kind of modern concrete will be necessary to maintain harmony between the built and the natural environment in the 21st century and beyond?

The civil engineering community is not idle on these concerns. For example, there are increasingly active research activities and emerging product lines on so called green or eco-concrete – concrete that utilizes a substantial amount of recycled industrial waste stream. This is obviously important due to the enormous concrete material flow as pointed out above. There is also sustained research on infrastructure durability problems – attempts to understand and model the deterioration processes of concrete infrastructure under realistic environmental and life loads. This is absolutely critical due to the dilapidating infrastructure conditions in many industrialized countries. The annual expenditures on infrastructure repair in Japan, Korea, Germany and the United States, for example, have passed annual outlays for new construction, and are expected to continue to tip the scale more and more over time. With increasingly difficult economic constraints in most countries, reversing the deterioration rate of civil infrastructure cannot depend on continuous increase of the budget for repair. The only hope of getting out of this quagmire is to develop new technology that counteracts typical deterioration mechanisms.

Are current research trends on eco-concrete and infrastructure deterioration leading us to technologies necessary to address the above economic and environmental concerns? Fundamentally, are we moving towards sustainable infrastructure for our built environment?

The answer to the above question is, at best, not clear. Let me explain. The material to build and to last in a given civil infrastructure, a bridge, for example, is one and the same. This obvious fact points to the need of a new kind of concrete that must be both green in the construction phase and durable in the use phase of the infrastructure. Yet, researches on eco-concrete and infrastructure durability are typically treated separately. Most research projects appear to address one or the other, but not both simultaneously. Thus, I would argue that new research directions are urgently needed to underpin next generation concrete technologies that combine both material greenness and infrastructure durability in field conditions, in order to attain infrastructure sustainability.

I used the wording “infrastructure durability in field conditions” as opposed to “material durability” in the last sentence for a good reason. There is increasing evidence that some high performance concrete that shows low permeability in the laboratory do not lend themselves to longer service period between maintenance events in, for example, bridge decks. This appears to happen due to cracking of the concrete in field conditions. Permeability of the concrete material in between cracks as confirmed by laboratory test then loses its value when water and aggressive agents enter through the cracks. The above observation has been made by various researchers. It is not a new idea. But it is worth repeating because it is important to keep this in mind when developing the next generation of eco-concrete that is durable – in the field.

Next generation concrete technology must be both green and field-durable in order to contribute to the harmony between the built and the natural environment in the 21st century and beyond.