Carbon Reduction

The New Structural Design Parameter

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Economically ensuring the strength and stability of structures while adequately addressing serviceability concerns has always been the main goal of structural engineers. As members of design teams, engineers typically leave the nonstructural aspects of the project's design requirements to others on the team. It's now time to acknowledge our role and responsibility in another aspect of design: reduction of emissions of carbon dioxide and other global warming potential (GWP) gases from the construction and operation of our projects.

Of course, it's not just structural engineers who need to take this into account – it's everyone. Human activities generate emissions of over 30 billion tons a year of CO_2. This has resulted in nearly a 40 percent increase in the amount of CO_2 in the earth's atmosphere since the 18^{th} century. Other greenhouse gases have increased as well. Scientific evidence shows that this is causing substantial problems with our climate, such as increased average land-ocean temperatures, and increased number and severity of storms and periods of drought. Engineers, who have an obligation to use Earth's resources responsibly, have a particularly important role to play in reducing GWP gas emissions.

Increasingly, attention is being paid to the resilience of structures – their ability to adequately perform when exposed to greater service loads as storms' intensities increase and shoreline development is subject to higher water levels and wave action. This is important work, and consistent with our fundamental engineering responsibility to protect the public. Yet, taking these changing conditions into account in our designs – also known as *adaptation* – is only part of our appropriate response. As we acknowledge that these changes are beginning to negatively affect our safety, we also need to acknowledge the activities we have engaged in that have led us to this point. Such actions will continue to create larger and long-term problems in the future unless we make changes to reduce those effects, which is called *mitigation*.

In 2009, the ASCE Board of Directors passed Policy Statement 488, *Greenhouse Gases*. This Statement acknowledged the problem of anthropogenic greenhouse gas emissions, and identified several actions that engineers can take to reduce these emissions. Identified strategies include use of existing technologies, as well as researching and implementing new technologies and materials that reduce emissions. How many of us have responded to this call for action to mitigate climate change effects?

Concrete, masonry, steel, wood, and other materials that structural engineers design and specify

have significant carbon dioxide-equivalent (CO_2-e) emissions, or footprints, released during their manufacture and construction. The emissions can fairly easily be quantified on a project. Rather than playing the materials off against each other (e.g. the classic "concrete versus steel" comparison), engineers can use strategies to reduce the emissions of the selected structural system:

- Concrete can be produced with less Portland cement, which generates nearly a pound of CO_2-e emissions for each pound of Portland cement in the mix, by using the pound-for-pound substitution of Supplementary Cementitious Materials (SCM). The required strength, cement content, and volume of material can also be refined and not over specified for the design task at hand. Where appropriate, one effective strategy is the use of Frost-Protected Shallow Foundations (FPSF).
- Concrete Masonry Units (CMU's) can frequently be produced with up to one-third less Portland cement at little or no additional cost, simply by requiring SCM to be used. Grout, which is frequently a cement-rich material, can be specified to have SCM as well. The cement content can usually be significantly reduced by avoiding the prescription-based specification in favor of prism tests and the strength method.
- Structural steel, with close to 1 pound of CO_2-e per pound of material emitted during manufacturing, fabrication, and erection, warrants extra effort in design optimization to reduce a project's tonnage. Specifying and designing products produced in Electric Arc Furnaces, which use more recycled content material than

Basic Oxygen Furnaces, can result in carbon reduction. Other potential life-cycle carbon-reducing strategies include Design-for-Deconstruction (DFD); that is, designing with the intention of deconstructing a structure at the end of its service life so the members can be reused, rather than recycled, the use of salvaged steel when circumstances allow it, and the use of innovative, material-efficient structural forms such as diagrid systems.

- The carbon footprint of structural wood products is usually less than concrete, steel, or masonry systems. Its use obliges the engineer to have an awareness of wood's possibilities and limitations. Also, wood's carbon footprint is dependent on the source of the material, including travel distance and management of the forest and the fabrication process. Jobsite waste can be minimized by careful planning and design choices.

Of course, carbon emissions of buildings do not stop at the completion of construction. Emissions associated with building operation, including heating and cooling over a building's service life, frequently exceeds the construction emissions. Here too, structural engineers can, and should, play a bigger role than they previously imagined was necessary. Structural thermal bridging, especially of continuous elements such as shelf angles and roof edge conditions, can be responsible for a significant portion of a building's envelope energy loss. Foundation insulation is not always addressed properly by the design team, particularly at slab edges and transitions in construction details. Effective, continuous insulation of buildings in heating and cooling climates is not always accomplished unless the structural engineer carefully coordinates the details with the project architect.

Many of these emission reducing measures can be advanced by the structural engineer with or without the explicit directive or encouragement of the rest of the project team, provided, of course, that there is no negative impact on the performance, construction schedule, or cost of the project. Other strategies, which may incur some costs, might need to be reviewed by the client and the rest of the project team before they are implemented. This is the really exciting and important challenge for structural engineers today. No matter what your experience level, taking on this challenge has the potential to lead one down an engaging path of shared learning and growth.

As engineers who are major specifiers and designers of carbon-intensive structural materials, we should educate ourselves and be leaders in advancing the mitigative actions necessary to reduce GWP gas emissions. It may be that the level of change needed will not happen until carbon is given some economic value. Should we, as structural engineers, assume a role as advocates in the political realm?

We need to fill the role that engineers have historically played: Solving society's problems and meeting its needs, in order to advance the human enterprise. It may be that history is calling us to be the engineers that we can be, in the largest sense of the word.▪

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