



Structural Engineers and Climate Change

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Anthropogenic (human-caused) emissions of greenhouse gases (GHG) into the atmosphere, particularly carbon dioxide, are causing dramatic changes to the earth's climate and oceans. These changes are described in detail in the authoritative and comprehensive reports written by the United Nations Intergovernmental Panel on Climate Change. Through building construction and building use, the construction industry contributes nearly 40% of total U.S. anthropogenic carbon emissions to the environment. As new building operational systems become increasingly energy efficient, the relative contribution of embodied carbon impacts to the overall carbon equation, including structural framing, becomes increasingly important. A new technical report by the ASCE SEI Sustainability Committee, *Structural Materials and Global Climate: A Primer on Carbon Emissions for Structural Engineers*, noted how structural engineers could play a key role in reducing total construction industry emissions through informed design and efficient structures. The following article summarizes this report.

Climate Change Basics

Climate change is defined as a change in global or regional climate patterns. Since the mid-to-late 20th century, the earth has been experiencing changes in global climate from the effects of global warming. This is primarily attributed to increased levels of GHG in the earth's atmosphere, the most abundant of which is carbon dioxide (*Figure 1*). Since

1900, the global average temperature has risen 1.5 degrees Fahrenheit, with most of the increase occurring in the last 40 years (*Figure 2*). This relatively sudden rise in temperature is destabilizing the earth's weather systems, causing new rainfall and drought patterns, more rapidly rising sea levels, more heat waves, increasing ocean acidification, and the potential for higher energy storms. The same trend can be seen if you look at the carbon dioxide levels in the atmosphere during the last three glacial cycles.

Contribution of Buildings to Climate Change

Environmental impacts from buildings are separated into two categories; operational impacts that occur during service life and embodied impacts that occur during construction, renovation, and demolition. Although embodied impacts are often assumed to account for 20% or less of total impacts and building operations for the remaining 80% plus, these percentage breakdowns may be misleading. First, they are based on a building lifespan of 50 years or greater, and many buildings are either refurbished or torn down before reaching that age. Second, buildings are becoming more energy efficient and striving for net zero energy use. Embodied impacts are therefore becoming increasingly significant.

It is imperative that we not only reduce emissions from building operations but reduce embodied impacts as well. Material-related GHG emission reductions will have a near-term impact on climate change, when it is most needed, whereas reductions

due to operating energy improvements are spread out over decades. Structural engineers need to be aware of the embodied carbon impacts of their design decisions and consider design choices to reduce emissions. By utilizing life cycle assessment, structural engineers can quantify the environmental impacts of the structures they design. See the ASCE-SEI technical report for more information.

Structural Material Contribution

The climate change impacts associated with the primary structural materials are briefly introduced below. Again, the ASCE-SEI technical report contains more information.

Concrete

The four basic components common to all concrete are cementitious materials, water, and coarse and fine aggregate. Although the cementitious material makes up the smallest proportion of a concrete mix design, it contributes approximately 90% of its carbon footprint when it is ordinary portland cement. This high contribution is attributable to both the energy used in the manufacture of portland cement and the chemical reaction, called calcination, associated with the conversion of limestone to cement. Other cementitious materials such as slag cement and fly ash are commonly used and significantly reduce the carbon footprint. The other processes in concrete production (mining, crushing of aggregates, and transportation of aggregates/cement) contribute the remainder of concrete's carbon footprint.

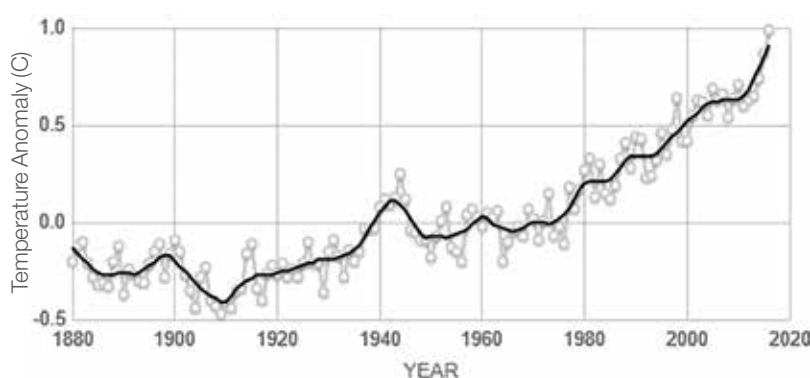
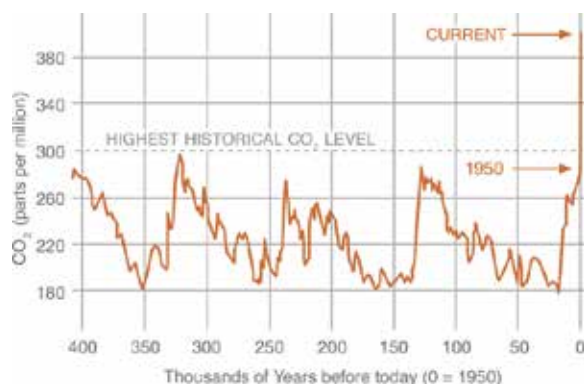


Figure 1. Carbon dioxide in atmosphere. Courtesy of NASA/NOAA. Figure 2. Global land-ocean temperature. Courtesy of NASA/NOAA.

Steel

The majority of structural steel consumed in the U.S. is produced and fabricated domestically. It is produced from one of two methods: the electric arc furnace (EAF), or the basic oxygen furnace (BOF). The majority of steel's carbon impact comes from the manufacturing process used. The EAF process creates half of the carbon dioxide emissions of the BOF process. One reason for this is the high recycled content (over 90%) of the raw material used by EAFs. This process is used for domestic hot-rolled structural steel and rebar production, while hollow structural sections and cold-formed steel are currently produced using both processes.

Wood

Wood "sequesters" carbon; as trees grow, they convert carbon dioxide from the air into wood fiber. As long as that wood fiber remains intact, the carbon is stored in it. When it burns or decays, the carbon is returned to the atmosphere. The carbon impact of wood comes from harvesting, milling, transportation, and the forest management. The role of forest management practices is difficult to quantify and is the subject of ongoing study.

Reducing Environmental Impacts of Buildings

Strategies for reducing the carbon impacts of the individual structural materials are discussed in the ASCE SEI Sustainability Committee technical

report. In addition to the material-specific strategies, broader approaches to reduce GHG emissions can be made, including:

- reducing material quantities
- mitigating thermal bridging
- utilizing structure as finish
- performance-based design
- using alternate structural systems than typically used for a particular building type
- utilizing functionally equivalent materials

- sourcing salvaged materials
- designing for deconstruction

All of these strategies, both at a material level and building level, must be taken with a holistic view to have the most beneficial impact. A designer needs to consider the environmental tradeoffs of design decisions, as well as the amount of potential saving a strategy offers and the timeframe for those savings. ■



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