Early evaluation is imperative if meaningful design changes are to be permitted.

conference preview

OPTIMIZATION OF STRUCTURAL EMBODIED ENERGY AND CARBON

BY WOLFGANG WERNER, AIA, LEED AP BD+C

A PERVASIVE DESIRE amongst those in the green building community is the need to increase the environmental efficiency of the built environment, both in terms of operational energy use and embodied energy. However, embodied energy and carbon impacts of buildings in general, and load-bearing structures in particular, are not yet considered as a matter of course during the design process. Consequently, the magnitude of these impacts is generally not well understood.

At Thornton Tomasetti, we are attempting to better address this issue. In conjunction with our AIA 2030 Commitment implementation efforts, an internal initiative was launched to quantify, record and aggregate the embodied energy and carbon values of the company's new construction structural design portfolio. Additionally, we developed an early design tool to evaluate the impact of fundamental structural design parameters on embodied energy and carbon.

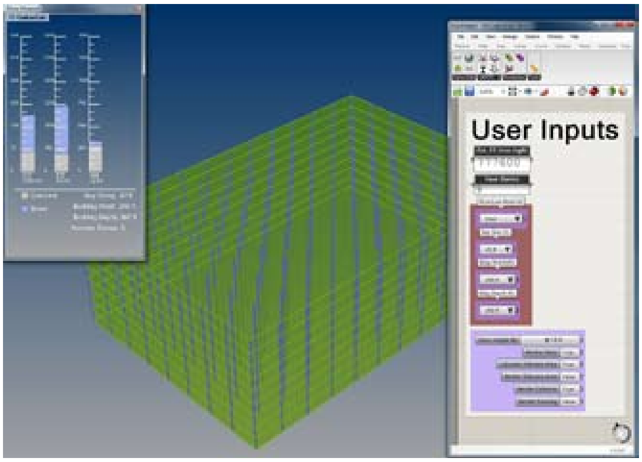
Why Buildings?

According to the U.S. Energy Information Administration's 2010 *Annual Energy Review*, about 42% of all primary energy used in the United States in 2010 was consumed by buildings. However, this total only includes the energy used to *operate* buildings. The embodied energy used to manufacture building materials, products and equipment and to construct buildings is categorized as industrial and transportation energy use, and is in addition to that 42%. In other words, buildings account for even more energy use when you consider everything that goes into building and deconstructing them.

For the past decade, many in the building design and construction industry have increasingly embraced design strategies and building technologies aimed at improving building operational energy efficiency. However, the embodied energy (the energy used, whether directly or indirectly, throughout the life cycle of a building for extraction/harvest of raw materials, manufacturing of building products, construction activities, demolition and disposal and transportation at all stages) and embodied carbon (the carbon dioxide, or equivalent, emitted as a result of that energy use) of the overall building energy picture have generally received a lesser amount of attention.

It is safe to say that a substantial portion of the total energy and carbon that is embodied in all building materials of a new construction project can be attributed to the structural systems. This is simply as a function of their great total weight compared to the sum of non-structural materials and systems, although non-structural elements clearly have their energy and carbon impacts as well.

Regardless, any strategy to reduce the embodied energy and carbon impact of a building needs to include a focus on the building structure. Yet most often, no evaluation takes place during the design process of how fundamental structural design parameters (e.g., comparing different materials or assemblies) affect a building's embodied energy and carbon totals.



A screenshot of Thornton Tomasetti's Carbon Efficiency Tool.

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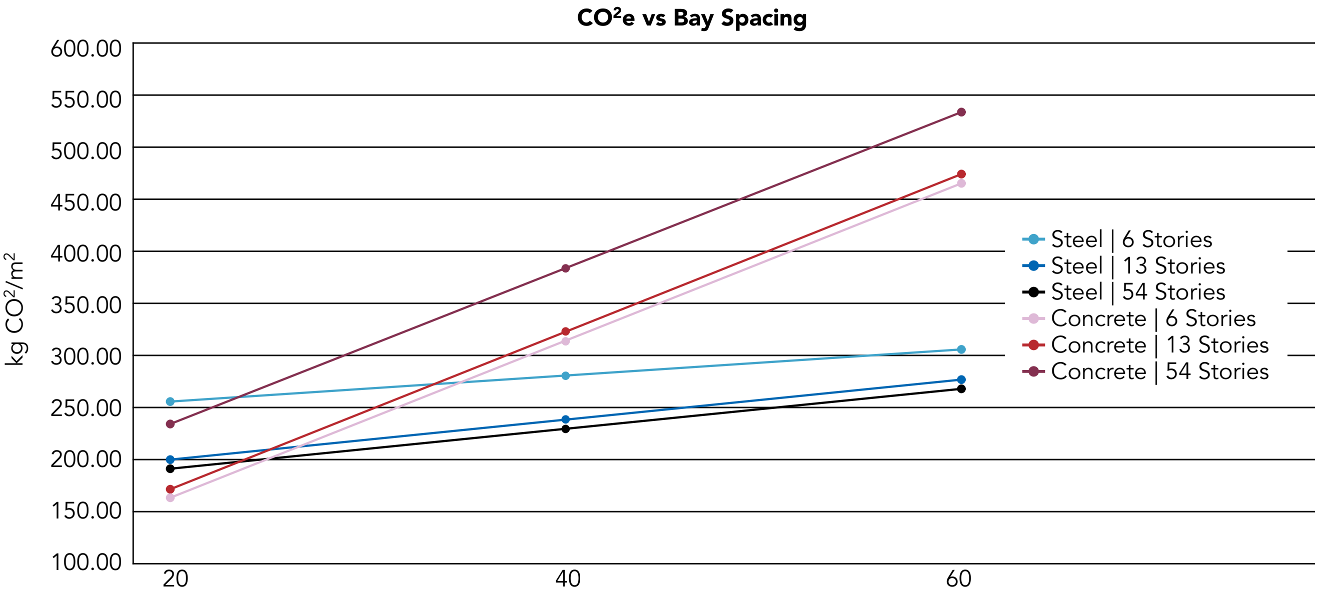

A chart summarizing output from Thornton Tomasetti's Structural Carbon Efficiency Tool.

Once a building design has progressed past the schematic design phase, many fundamental design decisions, particularly the ones related to basic building geometry, are typically "written in stone." Therefore, if a project has a goal of increasing its embodied energy and carbon efficiency, it must focus on this objective as early as possible before the design has "congealed" to the point where substantial adaptations are no longer possible.

To design for embodied energy and carbon efficiency requires, as a first step, the addition of these considerations to the range of "conventional" structural design criteria. Next comes an evaluation of the impacts of structural design decisions and approaches on embodied energy and carbon values. Because there is no established canon of "best practices for structural energy and carbon efficiency," this translates into the need to conduct project-specific evaluations based on viable structural design alternatives within the constraints set by other project requirements.

In Practice

Thornton Tomasetti developed an interactive early-design tool to evaluate how material selection, footprint and bay size affect structural embodied energy and carbon efficiency. This tool uses preliminary structural material quantities to provide instant embodied energy and carbon feedback. Similar to the concept of early design phase energy modeling, the output values should not be construed to predict actual totals; their purpose, rather, is to allow for the *estimation* of the relative magnitude of embodied energy and carbon impacts of different design alternatives.

We performed a case study using a simplified hypothetical design to evaluate how typical bay size affects embodied energy and carbon values for a rectangular building with a fixed total area. By changing the variable parameters (material, bay size, footprint) the approximate embodied energy and carbon impacts for principal design iterations within the defined constraints were calculated and are shown in the chart.

The chart reveals that in the context of this simplified hypothetical structure, there is a clear correlation between increasing bay size and increasing embodied carbon impacts, and that the rate of carbon impact increase is larger for concrete buildings than for steel buildings.

A Better Understanding

Given the magnitude of embodied energy and carbon impacts associated with the erection, renovation, alteration and demolition of buildings—coupled with the overarching imperative to reduce such impacts on a global scale—the design and construction industry must amplify its efforts to better understand the correlations between fundamental design decisions (geometry, massing, material selection, etc.) and embodied energy and carbon.

This is particularly pertinent to the structural engineering community as, by virtue of their sheer overall mass and the relatively high energy intensity of manufacturing many structural building materials, the embodied energy and carbon impacts associated with the load-bearing structure can be substantial. Because most of the fundamental structural design parameters that ultimately determine embodied energy and carbon efficiency are decided early in the design process, it is critical to evaluate embodied energy and carbon before these design parameters are set and irreversible. MSC

This article provides a preview of some of what the author will present in Session G7 at NASCC:The Steel Conference, April 18-20 in Dallas. Learn more about The Steel Conference at ***www.aisc.org/nascc****.*