Towards Zero Carbon: Developing a Roadmap for the Structural Engineering Profession and the Structural Engineering Institute, ASCE

Northeastern University, Boston, Massachusetts

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Workshop Pre-reads

Intent: To provide attendees with background information on the state of structural engineering profession and its path towards zero carbon.

Organization: This document includes:

1. Summary of SEI technical committee and program activities related to embodied carbon.
2. Summary of key readings and reports that set the stage for the workshop.
3. Extended bibliography that provides additional depth on pertinent topics.

Request to Participants: To prepare for the workshop, the following summaries and readings are included to ensure that all participants are aware of the present status of the structural engineering profession and embodied carbon.

Summary of SEI Technical Committee and Program Activities:

The Structural Engineering Institute (SEI) is a 30,000-member structural engineering technical institute of the American Society of Civil Engineers (ASCE). It is estimated that SEI members represent 2,500 companies, the majority having a structural specialty. SEI is comprised of two communities: a technical and a profession, and whose mission is to advance and serve the structural engineering profession. SEI produces some of the most influential technical and professional guidance for the profession and in the context of this workshop, advocates for the advancement of the structural engineer to be a leader in the sustainability and embodied carbon space. SEI regularly coordinates activities with organizations such as: NCSEA, IStructE, FEMA, and NOAA.

Two efforts within SEI to highlight that are related to workshop objectives are the SE 2050 Commitment Program and SEI Sustainability Committee.

SE 2050 Commitment Program:

The Structural Engineers 2050 Commitment Program aims to transform the practice of structural engineering in a way that is holistic, firm-wide, project based, and data-driven. By prioritizing reduction of embodied carbon, by using fewer and less impactful structural materials, participating firms can more easily work toward net zero embodied carbon structural systems by 2050. The commitment program came in response to the SE 2050 Challenge issued in 2019 by the Carbon Leadership Forum (CLF).

SE 2050 was formally launched in 2020 after several years of development with a database of embodied carbon of projects launched in 2021. Some current program highlights:

1. 170 structural engineering firms committed
2. Nearly 1,000 projects in the database
3. Updated free embodied carbon estimate tool, called ECOM
4. Updated project specification guidance
5. Quarterly calls with firm signatory representatives
6. Presentation of initial project data analysis including key findings

For further details about the SE 2050 commitment program, reference the website. And for a recent snapshot, view the 2023 Annual Report.

SEI Sustainability Committee:

The mission of the SEI Sustainability Committee is to (1) advance the understanding of sustainability in the structural community and (2) incorporate concepts of sustainability into structural engineering standards and practices. To achieve this, the committee has developed resources to enable the practicing structural engineer to design low embodied carbon systems. While the committee has been working for nearly two decades, two recent, notable committee publications include: (1) A Primer on Carbon Emissions for Structural Engineers, published in 2017 and (2) A Whole-Building Life Cycle Assessment Practice Guide, published in 2018.

At present, the committee is developing a Prestandard to provide a calculation methodology for assessing the embodied carbon of structural systems, which aims to set the standard of practice for the profession.

Key Readings and Reports

Achieving Net Zero Embodied Carbon in Structural Materials by 2050

The following executive summary outlines how the structural engineering profession may achieve net-zero embodied carbon by 2050. This white paper is a research-informed investigation by the Carbon Working Group of the SEI Sustainability Committee published in 2020.The full report can be accessed through the SEI Sustainability Committee website: How to Get to Zero 2025.

Executive Summary

Structural materials (i.e., steel and concrete) are responsible for over 10% of global carbon dioxide emissions. This paper outlines five paths to achieve a net zero-carbon future within the built environment. These paths include varying levels of adoption of 4 transition tracks: (1) design improvements, (2) greening the electrical grid, (3) material production improvements, and (4) carbon offsets.

Through design optimization, we estimate that between 10% and 25% of emissions can be avoided relative to current practices. Ways in which these emissions can be reduced include the avoidance of over-design, topology optimization, and performance-based design. Likewise, we estimate another 10% to 25% reduction in carbon emissions may be possible by specifying the appropriate materials. For example, concrete mix designs of the same compressive strength can vary significantly in their carbon emissions. Selecting concrete mixtures for both their structural and environmental performance can help structural designers reduce the carbon emissions of their structural systems by up to 40%. In addition, by reducing construction waste, for example through modular construction, we estimate between 5% and 10% reductions in carbon emissions can be achieved. Often the most effective design strategy to reduce carbon emissions from structural systems is to avoid new construction through retrofit and the adaptive reuse of existing buildings. Through retrofit, we estimate that between 5% and 15% of structural system carbon emissions could be reduced. Another design strategy to reduce carbon emissions is the use of substitute structural systems. By building with biogenic carbon (e.g., wood and straw), we estimate potential reductions in carbon emissions between 15% and 25%. Finally, design for resilience may be a contributing strategy, but insufficient research is available to estimate how much this strategy may contribute to embodied carbon reductions by 2050. The structural engineering community's adoption of these design optimization strategies has the potential to reduce carbon emission between 10% and 55%, showing a significant potential for reductions between present day and 2050.

By transitioning the electrical grid from non-renewable, carbon-intensive energy sources to renewable, carbon-free energy, the embodied carbon of structural materials could be reduced by 5% to 10%. Currently, the United States' electrical grid is already becoming increasingly carbon-free due to the decline of coal and state legislation requiring more electricity to be obtained from renewable energy sources. Overall, the reduction of embodied carbon from a renewable electric grid would vary depending on the material type. For structural steel, AISC estimates that carbon-free electricity would reduce the embodied carbon of steel by approximately 50%. However, for

concrete, the embodied carbon reduction due to carbon-free electricity would only be approximately 6%.

Improvements in the production of structural materials could provide an embodied carbon reduction ranging from 10% to 30%. Currently, material manufacturers have been steadily reducing the unit carbon footprints of their products over the past decades by incorporating more efficient manufacturing technologies. The carbon intensity of cement in the US has reduced by 33% within the past 50 years, though most U.S. production is already using modern, energy-efficient kilns so additional progress will likely not be as rapid moving forward. The greatest promise for U.S. concrete production is a move towards blended cements, such as those popular in the European markets. For steel manufacturing, the energy intensity dropped by 10% between 1990 and 1998. However, the rate of reduction is slowing due to the minimum theoretical energy required to produce steel. For wood products, carbon reductions are likely to come from sustainable forestry management practices, better understanding and measurement of carbon sequestration, and future harvesting and manufacturing efficiencies.

The final option to achieve net zero carbon emissions is the use of carbon offsets. Carbon offsets are investments in actions that reduce carbon emissions and should be third-party verified.

Combining design strategies, electrical grid improvements, and manufacturing improvements, the built infrastructure can transition to net zero carbon emissions by 2050 even without the use of carbon offsets.

Prestandard for Assessing the Embodied Carbon of Structural Systems for Buildings

The purpose of this prestandard is to set the standard of practice for assessing the embodied carbon of structural systems. The scope of this prestandard provides a calculation methodology for assessing the embodied carbon of structural systems. The intended audience is structural engineers and LCA practitioners. In its imperative text, the prestandard will define (1) how materials should be quantified during building design and construction, (2) how embodied carbon should be calculated and reported, and (3) rules of comparison for structural systems based on embodied carbon.

The prestandard has been developed by the SEI Sustainability Committee and is currently undergoing peer review with a target publish date in Q4 2024.

Other Related Resources

The following list includes resources and publications related to topics pertinent to the workshop.

Embodied Carbon

1. Embodied Carbon in the Built Environment: Measurements, Benchmarks and Pathways to Net Zero (Prasad et al. 2023) https://doi.org/10.1007/978-981-19-6371-1_3.
2. Bringing embodied carbon upfront (Adams et al. 2019). https://worldgbc.org/article/bringing-embodied-carbon-upfront/.

3. Carbon Leadership Forum Resources: https://carbonleadershipforum.org/resource-library/
4. IStructE Climate Emergency Resources: https://www.istructe.org/resources/climate-emergency/

Structural Engineering & Material Efficiency

1. Reducing embodied carbon with material optimization in structural engineering practice: Perceived barriers and opportunities (Smith et al. 2024). https://doi.org/10.1016/j.jobe.2024.109943.
2. Global potential for material substitution in building construction: The case of cross laminated timber. (D'Amico et al. 2021). https://doi.org/10.1016/j.jclepro.2020.123487.
3. Whole-life embodied carbon in multistory buildings: Steel, concrete and timber structures (Hart et al. 2021). https://doi.org/10.1111/jiec.13139.
4. Towards a structural efficiency classification system (Mena 20220). https://doi.org/10.1016/j.istruc.2020.04.012.
5. Towards net-zero carbon buildings: Investigating the impact of early-stage structure design on building embodied carbon (Torabi & Evins 2024) https://doi.org/10.1007/s11367-024-02287-w.
6. Reducing embodied carbon in structural systems: A review of early-stage design strategies (Fang et al. 2023). https://doi.org/10.1016/j.jobe.2023.107054.

Materials

1. Paving the way for sustainable decarbonization of the European cement industry (Cavalett et al. 2024). https://doi.org/10.1038/s41893-024-01320-y.
2. The sponge effect and carbon emission mitigation potentials of the global cement cycle. (Cao et al. 2020). https://doi.org/10.1038/s41467-020-17583-w.
3. Technology Roadmap - Low-Carbon Transition in the Cement Industry (IEA 2018). https://www.iea.org/reports/technology-roadmap-low-carbon-transition-in-the-cement-industry.
4. Buildings as a global carbon sink (Churkina et al. 2020). https://doi.org/10.1038/s41893-019-0462-4.
5. Efficiency stagnation in global steel production urges joint supply- and demand-side mitigation efforts (Wang et al. 2021). https://doi.org/10.1038/s41467-021-22245-6.
6. Global iron and steel plant CO2 emissions and carbon-neutrality pathways (Lei et al. 2023) https://doi.org/10.1038/s41586-023-06486-7.

Life Cycle Assessment

1. Buy Clean Policies: Overview & Implementation (CLF 2020). https://carbonleadershipforum.org/what-is-a-buy-clean-policy/
2. The EPiC database: Hybrid embodied environmental flow coefficients for construction materials (Crawford et al. 2022). https://doi.org/10.1016/j.resconrec.2021.106058.

3. The application of life cycle assessment in buildings: challenges, and directions for future research (Fnais et al. 2022). https://doi.org/10.1007/s11367-022-02058-5.

Circular Economy

1. Circular Construction. (Dan Bergsagel 2022). https://www.structuremag.org/?p=21903
2. Structural material demand and associated embodied carbon emissions of the United States building stock: 2020–2100 (Arehart et al. 2022). https://doi.org/10.1016/j.resconrec.2022.106583.