Sustainable, Resilient Buildings

Buildings both contribute to and are vulnerable to climate change. In the U.S., the heating, cooling, and operation of buildings and homes account for more than 40% of carbon dioxide emissions each year—more emissions than are produced by either transportation or industry. Meanwhile, the damage to property by the increasing number and intensity of hurricanes, tornadoes, and typhoons endangers lives and costs billions.

Any strategy for mitigating the effects of climate change must decrease energy usage and emissions from the building sector, as well as make structures more hazard-resistant. These measures will have substantial environmental, financial, and safety benefits for companies and individuals.

Research at the MIT Concrete Sustainability Hub (CSHub) supports the development of sustainable and resilient buildings by quantifying their energy use and hazard resistance. The CSHub is developing streamlined methods for quantifying the environmental and economic impacts of different material and construction systems.

BETTER TOOLS FOR ASSESSING THE LIFE CYCLE OF BUILDINGS

In focus groups and surveys with decision-makers in the building industry, CSHub researchers found that existing life-cycle assessment (LCA) and life-cycle cost analysis (LCCA) tools have several shortcomings. As a result, the environmental impact, cost, and performance of a structure over its entire lifespan may be inaccurately predicted, if they are predicted at all.

- There is a lack of consistency in methods for conducting LCAs/LCCAs.
- Existing tools are burdensome – they require too much detail about a proposed design and don't integrate well with the design process.
- Designers lack a comprehensive LCA/LCCA method or tool that addresses the complex tradeoffs between performance, cost, and environmental impact.

The CSHub is developing tools that address these gaps in LCAs/LCCAs. The goal is to enable designers, developers, owners, and other decision-makers to understand the costs and benefits of hazard-resistant and energy-efficient structures early in the design process—when building materials are typically selected.

- The CSHub is developing a streamlined LCA methodology that may be used early in the design process, which focuses on identifying key drivers of environmental impact and reducing the quantity and specificity of information required to conduct an LCA.
- The CSHub is also developing a method for integrating hazard resistance into LCCA by incorporating costs due to energy use, construction, maintenance, and damage from hazards.

CSHub researchers have conducted energy-related analyses in order to improve the application of energy-efficiency strategies in building design and LCA tools.

- They mapped thermal mass benefits (the ability of wall materials to help regulate the temperature in a building) of residential structures across the U.S., and showed climate to be a key determinant of the range of benefits from thermal mass.
- They conducted blower door tests for wood frame and ICF (insulated concrete form) homes in the U.S., which revealed no significant difference between the construction systems.

CASE STUDIES FOR RESIDENTIAL AND COMMERCIAL BUILDINGS

Researchers conducted LCAs/LCCAs for single-family housing, multifamily housing, and commercial buildings in a heating climate (Chicago) and a cooling climate (Phoenix). The scope of the LCCA, specifically, which pertained to single-family residential construction for these cities, focused on understanding the economics of typical ICF versus typical light-frame wood construction, and the associated cost of optimizing the ICF wall. For pairs of residential buildings, they compared wood frame and concrete structures; for the commercial buildings, they compared steel and concrete structures.

- The single and multifamily concrete residences analyzed in the study were shown to produce fewer greenhouse gas emissions than wood frame residences over a 60-year service life. The biggest impact occurs in single-family homes, which represent 80% of residential energy consumption in the U.S.
- The concrete homes use 6% to 12% less energy than code-compliant wood frame construction.
- The concrete homes produce 5% to 8% fewer greenhouse gas emissions than wood frame homes and exceed code requirements.
- Increasing fly ash from 10% to 50% in the concrete house reduces environmental impact by 12% to 14%.
- Reducing the thickness of the concrete wall from 6 inches to 4 inches is cost-effective and reduces emissions over the lifetime of the wall.
- The commercial office building built with concrete produced slightly fewer greenhouse gas emissions than a steel structure over a 60-year service life.
- Because of thermal mass, the concrete structural frame results in a 2% energy savings during operation.