Talking Points: Building Life Cycle Cost Analysis

Report from the Massachusetts Institute of Technology’s Concrete Sustainability Hub: *Methods, Impacts, and Opportunities in the Concrete Building Life Cycle*

Although the thermal mass attributes of concrete are known to significantly reduce heating and cooling needs, the energy consumption required to produce its key ingredient, cement, have raised questions to its environmental viability.

- To address this, MIT researchers conducted a life-cycle assessment (LCA) study to evaluate and improve the environmental impact and study how the “dual use” aspect of concrete — its ability to offer a highly resilient structure while providing thermal mass benefits for energy loads — affects the environmental footprint of the structure.
- Unlike many LCAs, the study includes all phases of the complete life cycle of a building, from acquisition of materials to construction, the use of the building, and finally demolition and end of life.

*Research benchmarks the comparative performance of concrete and competitive systems for single family, multifamily, and commercial construction through an objective and transparent process developed by MIT. The study sets a precedent for future building LCAs.*

- The study uses benchmarked models of all three building types based on work done by the US Department of Energy and its National Laboratories.
- The study based on 60-year lifetime, the widely accepted analysis period for building LCAs.
- The comparative environmental impacts are compared for one heating climate (Chicago) and a cooling climate (Phoenix).
- Buildings studied were designed to current building codes.
- Three types of buildings were studied:
  - Wood and concrete two-story single-family homes (2,400 sf)
  - Wood and concrete four-story multifamily buildings (34,000 sf)
  - Steel and concrete 12-story commercial buildings (500,000 sf)

*Total energy consumption for residential buildings accounts for approximately 18% of all global warming potential emissions in the United States.*

- Single-family homes represent 80% of total residential energy consumption.
- The study looks at wood frame and insulated concrete forms based on the differences in the amount of insulation in each wall assembly and the impact of thermal mass.
- The concrete home has more material by weight than the wood frame homes but 50% of the concrete and 70% of the steel reinforcement is assumed to be recycled at the end of the useful life of the project while 100% of the wood is assumed to be landfilled.
The study showed single and multifamily concrete residences produce lower greenhouse gas emission than current best practice code compliant wood frame residences over a 60-year service life.

- Concrete homes have higher embodied global warming potential associated with the pre-use phase of LCA, when raw materials are harvested and turned into construction materials, transported to the site and assembled into the finished home. However, this phase accounts for only about 2 to 12% of the home’s overall global warming potential.
- During the use phase, tight ICF homes in Chicago use 8.4% less energy than equivalent tight, code-compliant wood frame construction. ICF homes in Phoenix use 11% less energy than equivalent tight, code compliant wood frame construction.
- The study showed similar results when studying multi-family residences. During the use phase, ICF buildings in Chicago use 5% less energy than equivalent tight wood frame construction. In Phoenix, tight ICF buildings use 7.7% less energy than wood frame construction.

Operational energy of existing commercial structures in the United States accounts for approximately 35% of total electricity consumption.

- Past LCAs results vary widely because the studies have looked at different aspects of emissions and energy consumption.
- The concrete frame building has about 1.9 times more material by weight than the steel frame building. Fifty percent of the concrete and 70% of the steel reinforcement from the concrete frame is assumed recycled at the end of the useful life of the project while 98% of the steel frame is assumed recycled when the building is demolished.

MIT research found commercial office buildings built with a concrete structural frame produce slightly less greenhouse gas emissions over a 60-year service life than commercial structures built with steel frames.

- The concrete and steel buildings both have total embodied emissions of approximately 42 lbs of global warming potential emissions per square foot.
- Because 98% of the structural steel and 70% of the rebar salvaged from the building is assumed to be recycled at the end of life, that recycling adds a credit to the overall life cycle accounting.
- Because of higher thermal mass, an unfurnished concrete frame office building in Chicago and Phoenix will use about 3% less energy than a comparable steel frame commercial building.

Over the full life cycle, the annual energy savings can offset some of the first cost of construction. The total life cycle cost of an ICF wall is more expensive than code compliant wood frame, but higher future energy costs associated with wood-frame homes could reduce the relative difference between the two systems.
• ICF construction is more expensive construction than light-frame wood construction, increasing the price of a house by less than 5% over a 60-year service life.
• ICF construction will cost about $3 to $4 per square foot of wall area more to build than code compliant wood frame construction.
• During the use phase, ICF homes will result in annual energy savings compared to wood frame construction

MIT researchers also examined the most economical ways to lower the environmental footprint of a concrete home.

• Increasing fly ash or other SCM substitution from 10% to 50% in the ICF house reduces its environmental impact by 12% to 14%.
• Moving from a 6-inch to a 4-inch concrete wall is cost-effective, reduces emissions over the lifetime of the wall assembly, and should be considered in regions of the country where a 4-inch walls meets structural requirements.
• Increasing the thickness of the insulation layers flanking the concrete core of ICF construction can have cost effective benefits. Increasing the thickness of insulation from 2.5 inches to 4 inches represents the most cost effective means of increasing the thermal performance of the wall assembly because the increased cost of the insulation is less than the current market price of the carbon saved.