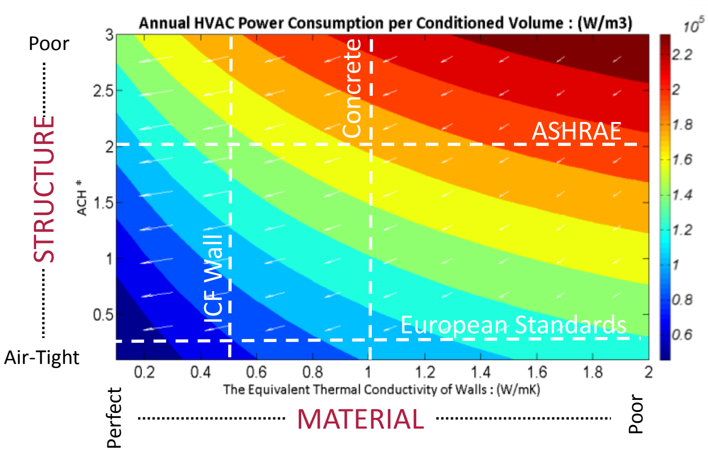
Homes: A Match for Concrete Innovation

Problem

According to a 2005 study of the U.S. Energy Information Administration, buildings consume roughly 40% of total energy use in the United States, and approximately 44% of this energy is utilized for heating and cooling. From a life-cycle assessment (LCA) perspective of buildings, the energy consumed during the design life translates into roughly 90% of the carbon footprint of buildings. The need for improving the energy efficiency of buildings was also recently introduced in Congress: The Sensible Accounting to Value Energy (SAVE) Act of 2011, if passed, will require all federal lenders to consider costs of projected energy efficiency when underwriting home mortgages. While HVAC system design continues to make progress in improving energy efficiency both actively and passively, one promising area is the development of innovation strategies that reduce the environmental footprint of homes by exploring the synergistic link between materials, structural and construction technology. The overall goal of our approach is to establish this link between architectural, structural and materials attributes for concrete, and to identify most efficient strategies for residential energy savings.



Sample output: Isovalue map of annual HVAC power consumption in function of air tightness (ACH*=Air Change per Hour under atmospheric pressure differential) and material performance (thermal conductivity) for a residential home unit in Boston, MA. ACH=2.0 is an upper ASHRAE-reported value. The arrays indicate the highest slope for residential energy savings.

Approach

We perform energy simulations of the transient heat and moisture equilibrium considering convection, infiltration, conduction and radiation for a representative residential home unit in thermal equilibrium with the ground. In the simulations, we vary architectural design parameters (length, height, wall thickness, internal mass, window percentage), material parameter (thermal conductivity, thermal mass, reflectivity, absorptivity), air tightness (ACH), and service parameters (number of residents, lightning). We evaluate the annual heating and cooling costs to maintain a constant inside temperature for different climatic conditions in the United States. For a given location, the approach provides a means to identify the most efficient strategies for residential energy savings.

Findings

Our results confirm that improving current US tightness levels to European standards would reduce by up to 40% HVAC power consumption. In return, the highest energy efficiency gains are obtained by simultaneously implementing materials innovation with higher tightness. For concrete homes, this suggests the use of wall-roof systems with continuous insulation and structure that combine low conductivity with fewer pathways for air infiltration compared to conventional stick built residences.

Impact

This research aims at moving LCA in the design space of architects, engineers and developers, by quantifying the link between energy costs and architectural, materials and construction technology design parameters. This research makes it possible to match specific material solutions with structural tightness levels that need to be implemented in order to enhance the energy efficiency of homes in the United States.

More

Research presented by Alison Ledwith and Mohammad Javad Abdolhosseini Qomi, graduate students in the CSHub, supervised by Prof. Franz-Josef Ulm.

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