Concrete Sustainability Hub@MIT – Life Cycle Assessment Research Brief – 8/2012

Optimizing Passive Thermal Mass

Problem

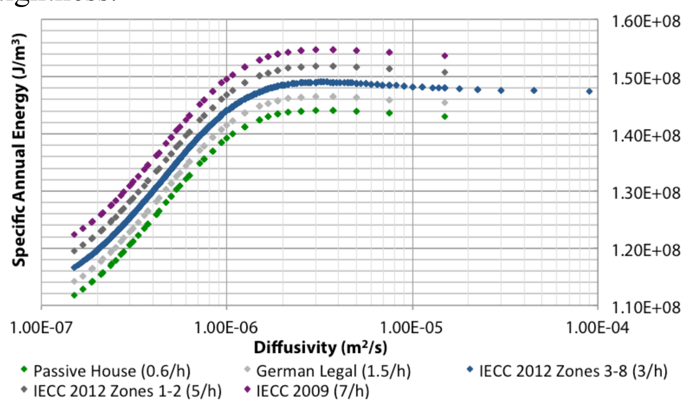
Passive thermal mass involves the use of envelope materials to store and release heat into the interior environment. Thermal energy storage is related to multiple factors: density, specific heat, conductivity and material thickness, as well as correlations between thermal mass, climate, geometry, and infiltration. Given the use of composite walls and slabs in modern residential construction, the research will determine if there are opportunities to optimize the use of thermal mass while minimizing energy consumption through the design of material and construction systems. The research focuses on multiple climates with results presented below for San Francisco.

Approach

We perform energy simulations using an idealized Cube Model to generate relationships between building parameters. The model uses equivalent envelope parameters and a prismatic shape to simplify building attributes. Key properties for material definition are density, specific heat, conductivity, and thickness. We start with a concrete wall with a thickness of 0.15m (6'') and a conductivity of 0.9W/m-K. These parameters are varied to identify opportunities for optimization that are climate dependent. In addition, a sensitivity analyses is used to determine whether passive thermal mass is impacted by other design decisions such as infiltration and geometry.

Findings

Our results show that passive thermal mass is governed by a density-specific heat master curve. Conductivity and thickness affect overall consumption and the saving potential of thermal mass. The optimal relationships between factors are climate dependent. In San Francisco, a climate that shows good thermal mass performance, the optimal conductivity of a 0.15m (6") thick wall is 0.4W/m-K, equivalent to an R-value of 2.13 $h\cdot ft^2\cdot {}^\circ F/Btu$. This is lower than a solid concrete wall but higher than conventional concrete wall systems. Increasing the thickness also provides energy savings. Wall thicknesses plateau between 0.25m (10") and 0.55m (22") and provide diminishing returns beyond 0.55m. Optimizing walls for thermal mass provides a 20-24% energy saving potential. Slabs, on the other hand, can be optimized by lower conductivities, 0.2W/m-K or an R-value of 4.26 $h\cdot ft^2\cdot {}^\circ F/Btu$, and greater thicknesses, 0.35m(14") or an R-value of 2.21 $h\cdot ft^2\cdot {}^\circ F/Btu$. Savings are in the order of 4-6%. As a result, optimizing walls provide greater opportunities to save energy over slabs. Another key factor is the relationship between infiltration and thermal mass performance: decreasing infiltration results in improved thermal mass performance. In addition, optimizing thermal mass in San Francisco provides for greater energy savings than increasing air tightness.



Sample output: Energy consumption for different infiltration rates and changing material properties for San Francisco, CA. Diffusivity is the ratio of thermal heat transmittance to thermal heat storage. In the graph above, materials of increasing mass have lower diffusivity whereas infiltration shifts the curves upward.

Impact

The research aims to identify relationships that optimize passive thermal mass performance while maximizing energy efficiency. These have implications on the design of wall and floor systems, from both a manufacturing, construction, and design point of view.

More

Research presented by Alison Ledwith, graduate student in the CSHub, supervised by Randa Ghattas and Prof. Franz-Josef Ulm.

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