Analyzing Temperature and Pressure Performance of a Natural Air-Circulation System

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Abstract : Perturbations in global environments and temperatures have heightened the urgency of creating cost-efficient, energy-neutral building techniques. Structural responses to this thermal crisis have included designs (including those of the building standard PassivHaus) with airtightness, window placement, insulation, solar orientation, shading, and heat-exchange ventilators as potential solutions or interventions. Limitations in the predictability of the circulation of cooled air through the ambient temperature gradients throughout a structure are one of the major obstacles facing these enhanced building methods. A diverse range of air-cooling devices utilizing varying technologies is implemented around the world. Many of them worsen the problem of climate change by consuming energy. Using natural ventilation principles of air buoyancy and density to circulate fresh air throughout a building with no energy input can combat these obstacles. A unique prototype of an energy-neutral air-circulation system was constructed in order to investigate potential temperature and pressure gradients related to the stack effect (updraft of air through a building due to changes in air pressure). The stack effect principle maintains that since warmer air rises, it will leave an area of low pressure that cooler air will rush in to fill. The result is that warmer air will be expelled from the top of the building as cooler air is directed through the bottom, creating an updraft. Stack effect can be amplified by cooling the air near the bottom of a building and heating the air near the top. Using readily available, mostly recyclable or biodegradable materials, an insulated building module was constructed. A tri-part construction model was utilized: a subterranean earth-tube heat exchanger constructed of PVC pipe and placed in a horizontally oriented trench, an insulated, airtight cube aboveground to represent a building, and a solar chimney (painted black to increase heat in the out-going air). Pressure and temperature sensors were placed at four different heights within the module as well as outside, and data was collected for a period of 21 days. The air pressures and temperatures over the course of the experiment were compared and averaged. The promise of this design is that it represents a novel approach which directly addresses the obstacles of air flow and expense, using the physical principle of stack effect to draw a continuous supply of fresh air through the structure, using low-cost and readily available materials (and zero manufactured energy). This design serves as a model for novel approaches to creating temperature controlled buildings using zero energy and opens the door for future research into the effects of increasing module scale, increasing length and depth of the earth tube, and shading the building. (Model can be provided).

Keywords : air circulation, PassivHaus, stack effect, thermal gradient
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