

A Design Framework to Balance Function and Sustainability in the Built Environment

Celine F. Manoosingh, Ph.D.
Georgia Southern University
Statesboro, Georgia

With an increasing consumer demand for environmentally friendly building products and materials, sustainability is becoming a paramount concern to key stakeholders in the construction industry. Insulation materials used in homes and commercial buildings play a primary role in their overall energy efficiency, and the production and disposal of the voluminous amount of insulation materials poses a significant environmental challenge. As sustainability becomes a primary goal for engineers, a decision making framework is needed to guide their choice of materials and processes; and then to carry out the evaluation of their chosen design.

The sustainable design process and the product developed through its application work concurrently with functionality and sustainability evaluation methodologies to cultivate a continuous loop of design, implementation, assessment and improvement. This work applies the proposed decision-making framework to building insulation because of the urgent need for sustainable and cost-effective solutions to reduce the significant solid waste generated by this material reaching the end of its functional life during building deconstruction and demolition. The primary objective of this study was to develop an alternative insulation that improves building energy efficiency and sustainability metrics across the life cycle of the building. First, the basic function of the redesigned insulation was tested by monitoring heat flux using experimental methods, as compared to the traditionally insulated wall. A one- dimensional heat flux model was then developed using heat transfer principles derived from Fourier's Law to estimate the heat flux through each insulation medium. Secondly, this work utilized life cycle assessment (LCA) to quantify the environmental sustainability of the design decisions associated with replacing the insulation. Employing LCA allowed the investigators to determine if the environmental benefits of material recovery would offset any additional environmental costs associated with the production and use of the alternative insulation. To address another key dimension of sustainability, a disassembly quantification system was developed. This system served to identify inefficiencies in the manufacturing and disassembly process to improve the product's recyclability and enhance material recoverability at the end of its commercial life. Life cycle cost and overall barriers to implementation will also be considered following the initial functional and environmental analysis.

By the process described by the framework, the insulation design was guided and evaluated to satisfy the objectives of improved environmental cost, effectiveness of thermal resistance and efficiency of design for disassembly. To evaluate the success of this approach, the insulation design developed for this research was then compared to the traditional polyurethane foam insulation in two contexts: functionality and environmental sustainability using life cycle assessment, and disassembly efficiency methods. The experimental test conducted in this study showed a decrease in heat flux by an average of 4%, and a savings of 1.2 metric tons of CO_2e over 20 years per 100 sq. ft. of insulation replaced. Experimental and environmental assessment revealed that significant opportunities exist to reduce the overall environmental and heat flux metrics associated with traditional building insulation. Results provide an alternative insulation design for use in construction, and a framework by which to assess the efficiency and environmental performance of sustainable building products.

Keywords: Sustainability, Life Cycle Assessment, Material Design, Energy Efficiency