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A Comparative Life Cycle Assessment: The Design of a High Performance Building Envelope and the Impact on Operational and Embodied Energy

Authors : Stephanie Wall, Guido Wimmers

Abstract : The construction and operation of buildings greatly contribute to environmental degradation through resource and energy consumption and greenhouse gas emissions. The design of the envelope system affects the environmental impact of a building in two major ways; 1) high thermal performance and air tightness can significantly reduce the operational energy of the building and 2) the material selection for the envelope largely impacts the embodied energy of the building. Life cycle assessment (LCA) is a scientific methodology that is used to systematically analyze the environmental load of processes or products, such as buildings, over their life. The paper will discuss the results of a comparative LCA of different envelope designs and the long-term monitoring of the Wood Innovation Research Lab (WIRL); a Passive House (PH), industrial building under construction in Prince George, Canada. The WIRL has a footprint of 30m x 30m on a concrete raft slab foundation and consists of shop space as well as a portion of the building that includes a two-story office/classroom space. The lab building goes beyond what was previously thought possible in regards to energy efficiency of industrial buildings in cold climates due to their large volume to surface ratio, small floor area, and high air change rate, and will be the first PH certified industrial building in Canada. These challenges were mitigated through the envelope design which utilizes solar gains while minimizing overheating, reduces thermal bridges with thick (570mm) prefabricated truss walls filled with blown in mineral wool insulation and a concrete slab and roof insulated with EPS rigid insulation. The envelope design results in lower operational and embodied energy when compared to buildings built to local codes or with steel. The LCA conducted using Athena Impact Estimator for Buildings identifies project specific hot spots as well illustrates that for high-efficiency buildings where the operational energy is relatively low; the embodied energy of the material selection becomes a significant design decision as it greatly impacts the overall environmental footprint of the building. The results of the LCA will be reinforced by long-term monitoring of the buildings envelope performance through the installation of temperature and humidity sensors throughout the floor slab, wall and roof panels and through detailed metering of the energy consumption. The data collected from the sensors will also be used to reinforce the results of hygrothermal analysis using WUFI®, a program used to verify the durability of the wall and roof panels. The WIRL provides an opportunity to showcase the use of wood in a high performance envelope of an industrial building and to emphasize the importance of considering the embodied energy of a material in the early stages of design. The results of the LCA will be of interest to leading researchers and scientists committed to finding sustainable solutions for new construction and high-performance buildings.

Keywords : high performance envelope, life cycle assessment, long term monitoring, passive house, prefabricated panels
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