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Environmental Life Cycle Assessment of Circular, Bio-Based and Industrialized Building Envelope Systems

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Abstract : The construction industry is accounted for one-third of all waste generated in the European Union (EU) countries. The Circular Economy Action Plan of the EU aims to tackle this issue and aspires to enhance the sustainability of the construction industry by adopting more circular principles and bio-based material use. The Interreg Circular Bio-Based Construction Industry (CBCI) project was conceived to research how this adoption can be facilitated. For this purpose, an approach is developed that integrates technical, legal and social aspects and provides business models for circular designing and building with bio-based materials. In the scope of the project, the research outputs are to be displayed in a real-life setting by constructing a demo terraced single-family house, the living lab (LL) located in Ghent (Belgium). The realization of the LL is conducted in a step-wise approach that includes iterative processes for design, description, criteria definition and multi-criteria assessment of building components. The essence of the research lies within the exploratory approach to the state-of-art building envelope and technical systems options for achieving an optimum combination for a circular and bio-based construction. For this purpose, nine preliminary designs (PD) for building envelope are generated, which consist of three basic construction methods: masonry, lightweight steel construction and wood framing construction supplemented with bio-based construction methods like cross-laminated timber (CLT) and massive wood framing. A comparative analysis on the PDs was conducted by utilizing several complementary tools to assess the circularity. This paper focuses on the life cycle assessment (LCA) approach for evaluating the environmental impact of the LL Ghent. The adoption of an LCA methodology was considered critical for providing a comprehensive set of environmental indicators. The PDs were developed at the component level, in particular for the (i) inclined roof, (ii-iii) front and side façade, (iv) internal walls and (v-vi) floors. The assessment was conducted on two levels; component and building level. The options for each component were compared at the first iteration and then, the PDs as an assembly of components were further analyzed. The LCA was based on a functional unit of one square meter of each component and CEN indicators were utilized for impact assessment for a reference study period of 60 years. A total of 54 building components that are composed of 31 distinct materials were evaluated in the study. The results indicate that wood framing construction supplemented with bio-based construction methods performs environmentally better than the masonry or steel-construction options. An analysis on the correlation between the total weight of components and environmental impact was also conducted. It was seen that masonry structures display a high environmental impact and weight, steel structures display low weight but relatively high environmental impact and wooden framing construction display low weight and environmental impact. The study provided valuable outputs in two levels: (i) several improvement options at component level with substitution of materials with critical weight and/or impact per unit, (ii) feedback on environmental performance for the decision-making process during the design phase of a circular single family house.

Keywords : circular and bio-based materials, comparative analysis, life cycle assessment (LCA), living lab
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