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Environmental performances of a timber-concrete prefabricated composite wall system

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Abstract

The improvement of environmental performance in building construction could be achieved by prefabrication. This study quantifies and compares the environmental impacts of a Concrete Glulam Framed Panel (CGFP): the basic configuration of this precast component consists in a Cross-Laminated Timber (CLT) frame structure supporting a thin reinforced concrete slab with an interior insulation panel and covered by finishing layers. The research investigates also alternative design of configuration with the substitution of different insulation materials in order to minimize the Embodied Energy and Carbon Footprint values.
The boundary of the quantitative analysis is "cradle to gate" including the structural support system; an IMPACT 2002+ characterization methodology is employed to translate inventory flows into impacts indicators.
Results present very low values for carbon footprint (60.63 kg CO_2eq m^{-2}) and the embodied energy values (919.44 MJ m^{-2}) indicate this hybrid precast structure as a valid alternative building constructions and processes.
A detailed discussion of the outputs is presented, including the comparison of the environmental performances depending on different insulation materials.

Peer-review under responsibility of the scientific committee of the International Scientific Conference "Environmental and Climate Technologies".

Keywords: precast panels; prefabrication; environmental impact; embodied energy; carbon footprint; cradle-to-gate; glulam; cross-laminated timber; reinforced concrete

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1. Introduction

Nowadays climate change is one of the most serious threats to human society and the reduction of CO_2 emissions is the main topic towards the global warning [1]. Buildings are widely responsible for environmental impact through consumption of resources, production of waste and emission of greenhouse gas. Construction sector includes a large amount of activities, from construction to management, from production to dismission: buildings in fact consume the 60 % of the raw materials extracted from the lithosphere [2], up to 40 % of global energy and led to 36 % of anthropogenetic greenhouse gas (GHG) emissions in industrialized countries [3, 4].

The general life-time carbon emission for a traditional house [5] is given by the primary materials, manufacture, transportation and construction [6]. In this sense the prefabrication of building components could be a validate strategy for optimize building process: it's shown the possibility to reduce the construction waste up to 52 % [7], due to the optimization of cut-off [8], affecting positively on energy, cost and time efficiency and also to reduce environmental impacts; for example, embodied energy indicator measures the energy consumed during extraction, processing, manufacturing, and transportation at all stages [9] and carbon foot print indicator measures the environmental impact of human activities on global climate [10].

In general there is an absence of detailed scientific research or case studies dealing with the overall environmental benefits of prefabrication [7] particularly the embodied energy savings resulting from waste reduction and the improved efficiency of material usage. Moreover the Concrete Glulam Framed Panel (CGFP) presents a particular hybrid configuration based on a CLT frame structure and a reinforced concrete cover. Different studies focus on materials, especially concrete and steel: Guggemos and Horvath [11] have identified and quantified the energy required for two construction of office buildings, the first with a structural steel frame and the second with a cast in place concrete frame, and findings revealed that the total life cycle energy use of both steel and concrete framed buildings were comparable. In general research undertook a comparative life cycle assessment (LCA) of the performance of the conventional construction method in relation to the use of a selected prefabrication method: about 44 % saving in embodied energy could be incurred from the use of precast concrete technology in relation to conventional construction of the same building. In a literature review Perez-Garcia et al. [12] show the environmental benefits provided by the Multilayer Structural Panels technology when applied to construct low rise residential buildings, evaluating the economic cost, the embodied energy and the amount of CO_2 emissions during the construction phase.

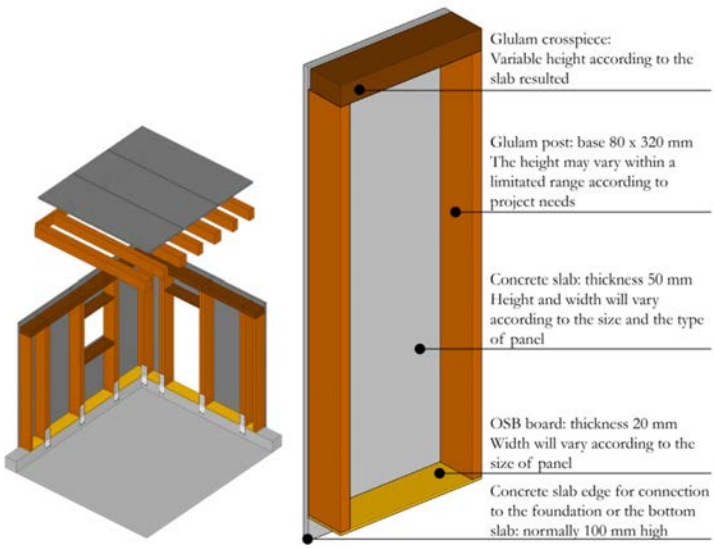

Fig. 1. CGFP model. (a) Model of a construction made by CGFP system; (b) characteristics and materials of a typical external wall component.