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Assessment of Cost and Embodied Carbon for Masonry Structures Located in Low and High Seismic Zones

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Abstract

Based on the sustainable criteria, the paper presents the analysis of cost, in euro/material, and environmental impact expressed by the embodied carbon in materials and heat gains through the glazing areas of two residential dwellings. The buildings have the same architectural design but different types of masonry, one is made of unreinforced masonry and is located in Cluj-Napoca (low seismic zone) and the second one is a confined masonry, located in Bucharest (high seismic zone). The results show that the quantity of materials, the embodied carbon in materials and the construction costs of buildings vary with up to 20% and emphasize the importance of their analysis in the building's design stage.

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Keywords: cost; masonry; seismic zones; embodied carbon.

1. Introduction

The National Law 372/2005[1] on energy performance of buildings amended and supplemented in 2013 by the Law159/2013[2] and republished in 2013[3], transpose the provisions of the European Directive 2010/31/EU(recast)[4] and require that buildings designed and constructed after 31 December 2020 to be "nearly zero-energy building (nZEB)"[2-4]. An nZEB is a building of high energy performance where the conventional energy required for heating and cooling it is almost zero or very low and/or replaced by energy produced from

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renewable sources[2-5]. Generally speaking in case of low energy or nZEB buildings, the solutions implemented in order to increase the energy performance become very effective[6,7], and may have as consequences the increases of the embodied energy in envelope members respectively of the buildings as a whole [6,7,8,9].

The good mechanical and thermal characteristics of ceramic blocks, the low cost and their affordability make the buildings made of masonry structure to remain an attractive solution for the residential dwellings designed in Romania, even though the seismic P100/1-2013[10] and masonry design CR6-2013[11] codes have become in the last ten years more and more restrictive, especially for buildings located in high seismic zones.

Embodied carbon and life cycle analysis represents useful tools which can be used in the construction field during the designing stage [6,7,8,9,12,13,14,15] in order to optimize the design solution adopted to building envelope members in accordance to the target imposed by Directive 2010/31/UE [4] and Romanian Laws [1,2,3,16] for nZEB buildings.

Considering that the buildings are designed to last at least 50-100 years [17], the civil engineers should be focused on their structural performance which is an indispensable issue especially in case of buildings located in seismic zones. A building vulnerable to seismic action may have a lower initial embodied carbon but will require a high embodied carbon and costs during operational phase in case of failures or collapse [18] and will put in danger the inhabitants life. The interest regarding the embodied carbon in the building sector became a necessity, as the Romanian codes are permanently changing in order to align to the requirements imposed by the European standards.

Based on all these issues, through a comprehensive approach, the paper presents a comparative analysis of two residential buildings, designed and located in two different seismic zones (low seismic zone - Case I and high seismic zone -Case II) and different climatic areas (climatic zones III - Case I, and II - Case II).

2. Methodology

The buildings were designed in accordance with the rules imposed by the Romanian codes for seismic P100/1-2013[10], and masonry design CR6-2013[11], and were considered to have the same geometrical features, for the envelope members (attic roof, glazing and walls areas).

The cost analysis of the masonry walls was estimated for both cases considering the average price of the component building materials recorded in the local market while the carbon emission was established considering the values extracted from ICE database - developed by Hammond and Jones, at the University of Bath [19] and according to specifications presented in SR EN 15804+A1:2014 [20]. The solar heat gain was determined according to C107/1-2005 [21] and Mc 001/1-2006 [22].

2.1. Building's description

The type of masonry is different from one case to another due to the requirement imposed by P100/1-2013 [10] seismic code. In this respect the building placed in the low seismic zone (a_g=0.10g) is an unreinforced masonry building (case I) while the building placed in the high seismic zone (a_g=0.30g) is a confined structure (case II) (Figures 1a,b).

The geometrical characteristics of buildings are the following: the attic floor and the slab above the ground area are 103.90 sqm, the walls are 138.3 sqm (case I) respectively 146.8 sqm (case II), and the windows areas are 19.96 sqm (case I) respectively 11.46 sqm (case II). The cross sectional areas of tie-columns are 25x25cm and 25x25cm for tie-beams in both cases.

The reinforced concrete class is considered to be C12/15, for all the confined elements. In the building design, two important aspects were taken into consideration in order to increase the heat gain: the south orientation of the glazing areas and their size, as can be noticed in Figure 1.