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Optimizing CO_2 emissions from heating and cooling and from the materials used in residential buildings, depending on their geometric characteristics

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ABSTRACT

The objective of this research was to obtain the environmentally optimal design of a building with the following starting conditions: constant constructed surface, constant volume, square floor layout, and a variable number of floors. For this purpose, the study evaluated the impact of CO_2 emissions stemming from the energy needed to maintain the building at a constant temperature of 19 °C in winter and 25 °C in the summer. Furthermore, one of the results was the CO_2 emissions curve from the manufacturing of the materials used in the construction of the building and the building envelope.

The energy consumed to cool and heat the building was calculated by means of the simplified method specified in the ISO/DIS/13790 standard. The building was thus regarded as a monozone with the consequent simplifications. The matrix method was used to calculate the building's structure for the purpose of obtaining the CO_2 emissions from the concrete and steel needed to construct it. The result obtained was the curve representing the CO_2 emissions, depending on building height. The source of these emissions was the energy consumption from heating and cooling as well as from the manufacture of construction materials. The results of the study indicated that the useful life of the building was a very important factor to take into account. The methodology used in this study could be used by building designers to design buildings with an optimal height for the reduction of negative environmental impacts.

1. Introduction

Environmental degradation is currently at great risk because of factors related to population increase, resource consumption, industrial activity, etc. This situation is causing serious environmental problems such as acid rain or the progressive disappearance of the ozone layer. Such problems are directly related to the emission of substances into the atmosphere as a consequence of fossil fuel combustion or the use of CFCs [1]. Many authors have mentioned the impact of the construction sector and industry on the environment, and have underlined how the responsible selection of building materials can minimize environmental impact [2]. The effect of construction activities can be assessed by calculating the CO_2 emissions as measured in kg or Tn.

The conception of an architectural project and its optimization from a social, economic, technical, and environmental perspective has been studied by various authors. For example, Depecker et al. obtained the ratio of building shape to energy consumption, based on the values resulting from the variation of the shape coefficient defining the geometric properties of the building [3]. AlAnzi et al. [4] analyzed the impact of building shape in relation to heating requirements in the case of offices. They studied the impact of building shape, orientation, and window surface. A series of equations were thus obtained that related energy consumption to these variables. Such energy consumption is directly related to atmospheric emissions, and depends on the energy generation sources.

Chel and Tiwari [5,6] studied the heat performance of dome-shaped houses constructed with environmentally-friendly building materials such as adobe. Based on embodied energy analysis, the energy payback time for the mud-house was found to be 18 years. The annual heating and cooling energy saving potential of the mud-house was calculated at 1481 kW h/year and 1813 kW h/year. The energy saving potential for both heating and cooling came to 5.2 metric tonnes/year.

Climate design is one of the most effective methods of reducing energy costs in building construction [7]. It is thus possible to design energy-efficient buildings by focusing on design and/or construction elements [8]. This justifies the efforts of the various agents that participate in the construction of such buildings. The

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