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Assessing the applicability of passive cooling and heating techniques through climate factors: An overview

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ABSTRACT

A review on climate parameters affecting applicability of passive and low energy heating and cooling techniques is presented. The study has been developed from existing research work results, and aims to serve as a first-stage assessment tool of the viability of these solutions at a particular location, depending on outdoor conditions to be faced. This contribution starts with a justification of comprehensive climate analysis as the first step to evaluate whether a specific passive or low energy solution would be efficient, or on the contrary, it would incur in higher energy consumption. Comfort requirements indoors as well as building typology and use are then briefly tackled as they would determine actual applicability. It continues gathering the weather variables affecting passive solar, natural ventilation, free cooling and evaporative cooling technologies. Key climatic information is then studied for 4 cities selected for their different summer climate conditions. Finally it ends with an overview of existing tools for representing climate information in bioclimatic design. Thus, the main target of this paper is to serve as a guide for an adequate preselection of the optimal passive energy solutions in buildings at a specific site, from existing research on climate analysis.

Contents

Abbreviations: DBT, Dry Bulb Temperature; RH, Relative Humidity; WBT, Wet Bulb Temperature; DPT, Dew Point Temperature; WBD, Wet Bulb Depression; DEC, Direct Evaporative Cooling; IEC, Indirect Evaporative Cooling

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1. Introduction

The current increase in primary energy consumption is widely recognized to be unsustainable. Consequently, actions are being driven in order to either avoid the misuse of resources or reduce the energy demand. Buildings are targeted as they constitute one of the most potential sectors in this sense. Particularly, they accounted for 40% of the total energy consumption in Europe in 2010 [1], percentage that has been increasing by around 1% per year since 1990 [2]. The largest contributors to this high and rising energy consumption are Heating, Ventilation and Air Conditioning (HVAC) systems.[3]. Moreover, the situation is worsened by the continuous development that leads to a rise in urban population [4], which spends more time indoors (85–90% on average) [5]. Provided that high quality of life is expected, consequent indoor comfort conditions result into a foreseeable increase of the percentage of energy consumed by HVAC systems.

Besides, it is estimated that most of the energy consumed in buildings could be saved. Consequently, legislation as the Energy Performance of Buildings Directive in Europe [1] is being introduced, and is constantly being revised to enhance energy savings within the sector. In this context, solutions to reduce energy consumption from its origin (demand) arises as the first step to be considered, before implementing further procedures proposed by current legislation. Having this into concern, climate analysis is a key point, due to the intrinsic relation between climate and energy demand for thermal comfort. It also highlights the importance of climate change on future energy trends [6].

1.1. Evaluation of passive techniques applicability

Passive techniques stand out among the possible solutions to reduce energy demand. They actually represent the oldest way to reduce heating and cooling loads, and nowadays are enhanced for having repeatedly proved to be sustainable alternatives to current conventional techniques [7,8]. However, their effectiveness depends directly on site conditions, varying not only from season to season but also along the daytime. Consequently, not every alternative might be a solution for one given location, but local climatic conditions must be carefully considered.

Thereby, to evaluate applicability of any passive solution a comprehensive analysis of the heating and cooling demand is needed. This requires a thorough study of the climate, as well as the provision of detailed information about the target building and about the indoor comfort expectations [9]. The evaluation of these three issues (climate, building and indoor conditions) constitutes an exhaustive study to determine whether the implementation of any technique is feasible or not at a particular location according to its specific conditions.

If we aim at simplifying the analysis, we might try to omit any of these three aspects as a first approach. Thermal comfort requirements are far from being a negligible factor on building energy consumption, as less strict conditions lead to lower energy demand [10]. Indeed, energy savings from 32% to 73% depending on climate conditions have been achieved in HVAC systems by loosening setpoint restrictions [11]. For their part, building characteristics (envelope, building use, etc.) directly determine wall conduction and internal heat loads. In fact, it has been calculated that around one third of the total cooling load in a building might be due to its envelope design, which is also closely related to the outdoor environment [12]. However, according to its direct and indirect influence, deep knowledge of climatic conditions is the principal requirement to perform a building design intended for the improvement of energy efficiency [13]. Moreover, it should be remarked that building characteristics are not easily modifiable once it is built. What is more, sometimes, implementation proposals of passive heating and cooling techniques are addressed in the early design stage, so no specific building can be considered. On the contrary, the aim at that point usually consists of refining possible building designs based on the application of viable passive techniques [9]. Therefore, a simplified analysis limited to climatic data could supply conclusive information on the feasibility of application of these passive heating and cooling strategies at a particular location.

In this respect, commercial environmental bioclimatic design tools are complex and not extensively used, which demonstrates that a simpler climate analysis tool for the initial design planning is necessary [13]. With this aim, analysis of local climatic conditions must be stated as the first step when estimating heating and cooling loads to analyze equipment viability and optimize systems sizing [12].

1.2. Scope of the review

The purpose of this review work is to compile existing results on the applicability and potential of selected passive and low-energy strategies, according only to climate operating conditions. Once the possibility of focusing the analysis on the climate has been justified in the first part of this introduction, Section 2 relates climate variables with the heating and cooling loads that these strategies must face. Then the importance of the reliability of climatic data is also highlighted.

Target passive and low-energy solutions have been selected for being mainly dependent of climate variables. To pursue the objective of studying their interest according to the climate, in Section 3 we identify specific climate factors studied in different research work for each proposed conditioning solution, together with those results concerning applicability ranges or degree of interest. This information is gathered into tables to provide a global overview. Subsection 3.1 describes how climate conditions need to be studied