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The Adaptive Comfort Factor in Evaluating the Energy Performance of Office Buildings in the Mediterranean Coastal Cities

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Abstract

This paper examines the thermal comfort conditions during summer and winter in an existing office building in an urban context. It investigates and correlates the results obtained from a questionnaire survey, conducted during summer and winter, with the two comfort models – for mechanically ventilated spaces and non-mechanically ventilated ones - in order to determine the most appropriate one for the energy performance evaluation of the office buildings in the coastal Mediterranean region. The study is carried out within the framework of the Urban Europe project Smart Urban Isle and it specifically refers to the Cyprus case study. The project considers the bioclimatic design of the buildings and of their urban environment, as well as potential energy management systems, in order to define and evaluate urban isles as a basic unit of energy measurement for Smart Cities. The Cyprus case study focuses on the impact of the thermal comfort Standards on the energy performance evaluation of the buildings and it promotes the sustainable and energy efficient design by selecting the most appropriate Standard to assess the thermal comfort for occupants.

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Keywords: adaptive comfort; energy conservation; Standard EN 15251, office building

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1. Introduction

It is well established that when examining the energy efficiency and the flows of energy in a building or an urban complex, the thermal comfort of the occupants is amongst the most significant parameters to be considered. The thermal comfort Standard to be used for the comfort evaluation of the users has a direct impact on the assessment of the energy performance of the buildings and therefore on their predicted energy demand and consumption.

The energy intensity in Cyprus for 2015 was found to be higher than the mean EU28 [1], with estimations that by 2030 the electricity consumption in Cyprus may be up to 2.9% higher than the reference scenario [2]. Moreover, energy consumption in buildings in the EU amounts to 40% of final energy consumption [3], with large amounts spent

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towards creating comfortable thermal environments for the inhabitants. This sector represents an opportunity to halt the escalating energy demands of buildings, by opting for low-cost adaptive strategies, such as allowing building occupants to interact with the building (e.g. by opening windows) and create thermal conditions that are tolerable without increasing energy consumption [4]. Non-residential dwellings account for almost 14% of total building floor area, of which approximately 26% represents private and public office spaces [5] and have added more than 1 million square meters of built space during the last decade. With estimations that almost only 1% of the building stock is newly added each year, 99% of the building stock is made up of existing buildings which are responsible for large amounts of energy use and the associated carbon emissions [6].

The present study examines satisfaction of occupants with the thermal conditions of an office building in an urban setting in Limassol, Cyprus, by means of surveys complemented by on-site measurements to record thermal comfort based on PMV and relative to the European Standard EN 15251 [7].

The literature review, in continuation, focuses on the thermal comfort factors, its significance and the methods used for its assessment, with special attention given to the evaluation of indoor thermal comfort in office spaces.

2. Indoor thermal comfort

Indoor environments designed based on the European Standard EN 15251 [7] for mechanically conditioned spaces, produce thermal monotony; resulting in indoor environments that are significantly dissociated from the outdoors and the actual indoor conditions differing from the estimated ones when the space is in operation due to occupant behavior [8]. The adaptive Standard [9], which is used for evaluating the thermal comfort in free running – not mechanically ventilated - buildings, in most cases represents more accurately the comfort practices and adaptation mechanisms of the occupants than the Standard for mechanically ventilated buildings. In effect, it provides a more coherent option that opens up many cost-effective, low energy design alternatives for the conditioning of spaces [10].

For instance, a simulation study showed that it is possible to create “Zero Energy Houses” by adopting different combinations of design measures in free-running buildings, without using unfamiliar construction techniques or having to make major changes in the lifestyles of urban dwellers [11].

As such, the majority of both residential and non-residential buildings, in Cyprus and across the EU, are outdated and require refurbishment. Special attention is given to the publicly owned buildings under the 2012 Energy Efficiency Directive (EED, 2012/27/EU) [12], according to which each member state is bound to ensure yearly renovations for buildings owned and occupied by the central government in order to at least meet the minimum energy efficiency levels [13]. Renovations of public buildings to meet the desired criteria should also take into consideration the aspect of thermal comfort of the buildings’ occupants, in order to achieve optimal energy performance of the buildings and simultaneously improve productivity and the general well-being of the users. It is therefore of paramount importance to utilize appropriate Standards for the assessment of thermal comfort.

The early Standards of thermal comfort that were developed (e.g. the initial form of ASHRAE Standard 55 and ISO 7730) focused mainly on the heat balance model, where only environmental factors (temperature, thermal radiation, humidity and air speed) and personal factors (activity and clothing) were considered to influence thermal comfort. However, it soon became clear that adjustments needed to be made, as occupant behavior was found to deviate from what was proposed by the Standards [14]. Gradually and with extensive research, adaptive thermal comfort Standards were established, accounting for behavioral interactions of occupants in order to create comfortable thermal conditions for themselves and the fact that comfort is also affected by the outdoor climatic conditions of the area (9). The adaptive thermal comfort model is now supported by Standards such as the International Standard ASHRAE RP884 and the European Standard EN 15251 [15].

The European Standard EN 15251 considers thermal comfort from a physiological perspective, while in addition taking into account the importance of the wider environmental context in which the occupants act. In essence, the Standard EN 15251 accounts for the fact that expectations for thermal comfort are different for occupants of naturally ventilated buildings in comparison to those of individuals accustomed to indoor thermal environments that are mechanically regulated [7]. On the other hand, the Standard EN ISO 7730 ignores the variations in the expectations of occupants; viewing them instead as passive recipients of thermal stimuli, focusing only on the Predicted Mean Vote (PMV) or Predicted Percentage of Dissatisfied (PPD) and factors that influence local thermal discomfort, such as radiant temperature asymmetry and draught [7,16,17]. Nonetheless, it is now known that dwellers who are accustomed