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Energy and comfort performance of thermally activated building systems including occupant behavior

Dirk Saelens*, Wout Parys, Ruben Baetens

Division of Building Physics, Department of Civil Engineering, K.U. Leuven, Kasteelpark Arenberg 40, P.O. Box 2447, 3001 Heverlee, Belgium

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A B S T R A C T

In building simulations it is common practice to use standardized occupant behavior and internal gains. Although this is a valid approach for designing systems, the probabilistic nature of these boundary conditions influences the energy demand and achieved thermal comfort of real systems. This paper analyzes the influence of occupant behavior on the energy performance and thermal comfort of a typical office floor equipped with a thermally activated building system (TABS). A multi-zone TRNSYS model with 10 adjacent zones per orientation for a typical moderate Belgian climate is set up. First, the energy performance and thermal comfort of thermally activated building systems (TABS) are compared with the performance of idealized cooling with standardized user behavior. TABS are able to deliver good thermal comfort but show to have a higher energy demand. Secondly, probabilistic occupant behavior was implemented in the TABS simulations. The influence of the occupancy rate, the shading device use and switching of the lights are analyzed by defining user profiles. It is shown that occupant behavior may have an important influence on the cooling demand and thermal comfort. However, as long as good solar protection is foreseen and operated in a correct way, TABS are able to cope with different user behavior modeled in this paper. In this case, normal daily stochastic processes do not considerably affect the cooling demand and thermal comfort during summer.

1. Introduction

World-wide 38% of the total energy use is used for operating the building stock [1]. In 2005 more than 66% of which was used for HVAC and lighting in the USA [2]. Because of the environmental impact of energy use, the depletion of energy resources and the economical consequences, the interest in energy conscious, sustainable office buildings has increased considerably. In order to design such office buildings, alternative heating and cooling systems such as thermally activated building systems (TABS) have gained interest.

TABS consist of pipes, embedded in the concrete floor, through which water flows to provide heating and/or cooling. As a large fraction of the cooling is exchanged as radiation, TABS are considered comfortable because typical draught problems encountered with convective systems are reduced [3,4]. Based upon simulations and measurements many authors demonstrate that TABS are able to reduce the peak cooling requirements [3,5–7]. TABS are considered energy efficient as they are high temperature cooling systems [8]. Because of the high thermal capacity of the floor, specific control strategies are necessary to obtain good thermal comfort as well as a high energy efficiency [5]. Lehman et al. [9] point out that many analyses are presented for single offices only. Rijksen et al. [7] compare the performance of TABS with traditional HVAC systems for an entire building. Commonly, building simulations are done with average occupation schedules for example available from EN 13790 [10]. However, the real occupation differs from these design conditions [11]. While it may be argued that the average energy demand may be obtained from average occupancy profiles and that the individual occupancy schedules are tackled with the individual control devices in the offices, this is less straightforward for TABS. It is common to control TABS in zones with similar cooling demands. As this control strategy is not able to control individual offices, both energy performance and thermal comfort of individual offices may differ substantially from the average situation.

In this paper the effect of occupant behavior on the energy performance and thermal comfort is analyzed. A simulation environment with 2 × 10 individual office cells is set up and a probabilistic approach to define the behavior of the occupants is implemented. Different user profiles are defined to assess the ability of the TABS to cope with different thermal loads.

* Corresponding author. Tel.: +32 16 321343; fax: +32 16 321980.
E-mail address: dirk.saelens@bwk.kuleuven.be (D. Saelens).

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