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ScienceDirect
Energy and Buildings 39 (2007) 593–598
ENERGY and BUILDINGS
www.elsevier.com/locate/enbuild

Application range of thermally activated building systems tabs

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Received 19 August 2006; received in revised form 19 September 2006; accepted 20 September 2006

Abstract

This paper presents application range and functionality of thermally activated building systems (tabs). Tabs are increasingly used for energy efficient and economical cooling and heating of commercial buildings. Thereby, the building structure is used as thermal storage allowing the use of renewable energy sources. Based on a simulation study for a typical office building the aspects of thermal comfort, maximum permissible heat gains in the room and the re-cooling of the building mass are analysed. It is shown that depending on the maximum permissible daily room temperature amplitude with tabs typical heat gain profiles with peak loads up to around 50 W/m^2 floor area can be managed. However, the transitional (mid-season) periods with already high solar gains and still restricted comfort range, in most cases will be decisive for the dimensioning of tabs, thus limiting maximum loads to lower values. The results also show that processes on the room side are almost unaffected from the processes on the supply side. In the cooling case, this allows for the re-cooling period of the fabric being extended to 24 h a day with accordingly ''high'' supply temperatures and peak load reductions of up to 50%. The results given may serve as orientation guide whether a tabs may be applicable in a specific building, and provides relevant parameters for the dimensioning of tabs.

Keywords: Thermally activated building systems; Concrete core cooling; Low energy cooling; Peak load reduction

1. Introduction

A growing recognition of the need for energy efficiency and the benefits of passive heating and cooling systems for room comfort has prompted the search for new heating and cooling concepts for buildings. Thermally activated building systems [1] have been shown to meet these new requirements in terms of both performance and cost.

As the name suggests, thermally activated building systems (tabs) are specifically designed to integrate the building structure in the overall energy strategy of the building. Particular building elements, typically structural floors and slabs, serve as an energy storage whose dynamic thermal behaviour is exploited to provide either cooling by the absorption of energy from the internal environment or space heating through the release of stored energy. Such use of the building's thermal mass serves to flatten out peaks in energy demand.

The large area of these thermo-active surfaces permits substantial heat flows between space and structure, even for relatively small temperature differences. This, in turn, allows the use of low energy cooling or heating sources, such as the ground, outside air or recovered process heat.

This article outlines the potential and limitations of thermally activated building systems in terms of achievable comfort and maximum total heat loads in office buildings.

2. Room comfort in buildings

Human thermal comfort is affected by a number of parameters, namely according to Fanger's comfort equation [2], and the respective standard EN ISO 7730 [3]. Fig. 1 shows the predicted percentage of dissatisfied, based on this comfort equation, for sedentary office work and different types of clothing.

As can be derived from Fig. 1, a total acceptance (0% of dissatisfied) for a given room climate cannot be reached. EN ISO 7730 [3] thus specifies three comfort categories A, B and C with a maximum permissible rate of dissatisfied of 6, 10 and 15%, respectively. For office spaces, the categories A and B are appropriate. Depending on the applicable comfort category and

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doi:10.1016/j.enbuild.2006.09.009

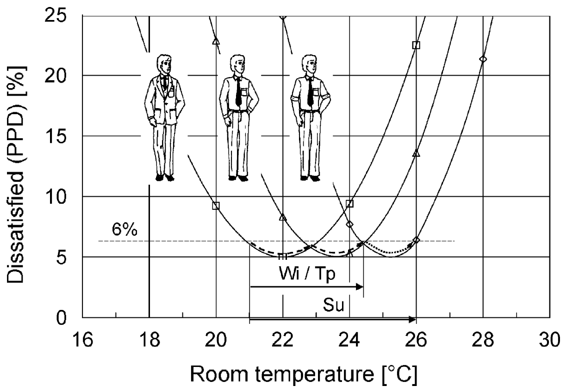

Fig. 1. Predicted percentage of dissatisfied (PPD) for a range of room temperatures (operative temperatures) and different clothing (sedentary activity). Comfort ranges for winter/transitional period and summer. EN ISO 7730 [3].

clothing habits varying comfort ranges arise for different seasonal periods (Table 1).

The permissible room temperature (operative temperature) range for the winter/transition period can be derived to be 3.5 K (6% dissatisfied) and 5.5 K (10% dissatisfied). For the summer period, the respective ranges are 5.0 K (6%) and 7.0 K (10%). As these figures suggest, room comfort is not dependent on a constant internal temperature and fluctuations are possible within predetermined limits. Occupants are also free to adjust their attire to the specific temperature conditions. This permissible comfort range forms the basis for the optimization of heating, ventilation and cooling system capacities to achieve maximum energy efficiency. Especially with tabs, the room temperature is floating with a certain amplitude during the day. Thus, the respective permissible temperature ranges are key elements for the design of such systems.

3. Use of low energy heating and cooling sources

The highly insulated building envelopes common today create new conditions for the heating and cooling of internal spaces. Given the dramatic reduction in energy needs, the focus is now on the use of low energy heating and cooling sources. At the same time, the fully glazed façades favoured by contemporary architects entail higher gains that frequently cancel out the enhanced performance of glazing systems. Solar gains thus continue to play a pivotal role, particularly in summer and the mid-season months (transitional periods). Apart from these external gains, the internal environment is also subject to heat gains from occupants, equipment and lighting – with the result that modern-day office buildings require cooling practically all year round.

The problems commonly accompanying the exploitation of natural cooling sources for buildings relate to the time lag governing their use or their insufficient availability for the required cooling power.

3.1. Time lag

As high room temperatures tend to coincide with high outside air temperatures, the direct use of external air as a cooling source may normally be ruled out. A suitable storage system is therefore needed to bridge the gap between the day-time cooling demand and night-time cooling availability.

Such a storage system may also offer an efficient solution in cases where, for instance, a dual-purpose use of refrigeration plant is contemplated. Such a unit may serve to cool supply air during the day-time while providing additional storable cooling capacity at night for use the next day.

3.2. Insufficient availability

The maximum heat and cooling output of natural energy sources tends to be limited. In the case of cooling, for example, the required actual demand frequently exceeds the potential output from a particular source. Here, as in the previous case, an appropriate storage system is needed to meet the loads imposed by internal spaces, even for lower cooling outputs.

Given the high cost of floor space, one particular drawback of storage systems, such as those using cold water is their substantial size. By comparison, the use of the existing building structure, specifically floors and slabs, as the main storage system offers a much more cost-effective solution. The high density and specific heat capacity of concrete may be exploited to create buildings with high thermal mass. Efficient use of the building structure as a thermally activated building system may then be achieved by means of a suitable management concept like that needed for any storage system.

4. Principles of thermally activated building systems

The principles and the use of a thermally activated building system (tabs) are depicted by the diurnal temperature cycle given in Fig. 2. A minimum room temperature of 21 °C is assumed for the morning (point (1)). The heat gains in the interior arising from the building occupants, equipment and solar radiation from the outside push up the air and room temperatures to around 26 °C ((1)–(3)) in the course of the day. The convective fraction of the heat sources accounts for the greater part of the temperature rise ((1)–(2′)). The difference

Table 1
Permissible room temperature ranges for a maximum of 6 and 10% dissatisfied, respectively

Type of clothing	Seasonal applicability of clothing	Comfort range (°C) maximum 6% dissatisfied	Comfort range (°C) maximum 10% dissatisfied
Jacket	Wi/Tp-Su	21.0–23.0	20.0–24.0
Long-sleeve shirt	Wi/Tp-Su	23.0–24.5	21.5–25.5
Short-sleeve shirt	Su	24.5–26.0	23.5–27.0

Wi, Winter; Tp, transitional periods; Su, summer.