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Performance of EN ISO 13790 utilisation factor heat demand calculation method in a cold climate

Juha Jokisalo *, Jarek Kurnitski

HVAC-Laboratory, Helsinki University of Technology, P.O. Box 4400, FIN-02015 TKK, Finland

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Abstract

The applicability of the utilisation factor method EN ISO 13790 is studied in modern Finnish buildings in the cold climate of Finland. The heat-demand results of EN ISO 13790 are compared against a validated dynamic simulation tool. It is shown that, with the default values of the numerical parameters of the utilisation factor, EN ISO 13790 gives in Finnish conditions as much as 46% higher or 59% lower heat demand of the building compared to the simulation tool, depending on the type of the building and its thermal inertia. The results of EN ISO 13790 can be calibrated for the residential buildings with the correct selection of the numerical parameters for Finnish conditions. With the new values of the parameters, the results are in good agreement in most cases; however, the maximum difference between the methods remained 29% for highly insulated residential buildings. For office buildings, heat demand was strongly underestimated in all the cases by the monthly method EN ISO 13790 regardless of the values of the parameters. The results of the study indicate that the monthly method EN ISO 13790 with new determined numerical parameters is reasonably applicable for residential buildings, but not applicable for office buildings. Therefore, the other methods of prEN 13790, i.e., simple hourly or detailed simulation methods, should be used for office buildings.

Keywords: Energy performance; Heat demand; Utilisation factor; Heat gains; Time constant; Thermal inertia; Building structure; Dynamic simulation

1. Introduction

The European energy performance directive for buildings (Energy Performance Building Directive—EPBD) states that the energy efficiency of buildings has to be calculated in the member states [1]. The member states are implementing the EPBD at the national level by taking into account local climate and conditions, requirements for indoor climate and cost efficiency. An objective is that the directive comes into force in all member states in 2006.

The European Commission has given a mandate to CEN for the production of standards for the implementation of the EPBD. As a consequence of the mandate, CEN is updating and producing standards that are relevant to the EPBD. Under the mandate, CEN is also extending the standard EN ISO 13790 (Thermal performance of buildings–Calculation of energy use for space heating) [2] to include the calculation of space cooling and a simple hourly calculation method and calculation procedures for a detailed simulation method, while the monthly calculation method remains in the revised prEN 13790 [3].

In the current Finnish building code, D5 1985 [4], thermal inertia is not taken into account, because it has only a minor effect on heat energy consumption in older, less insulated, buildings with relatively low heat gains in the cold climate [5]. Finland is considering an implementation of the monthly method of the European standard EN ISO 13790 as part of the calculation method for the energy performance of buildings. The applicability of the calculation method of a utilisation factor for internal heat gains suggested by the standard is studied and new numerical parameters of the utilisation factor suitable for Finnish conditions are determined.

2. Methods

The study is carried out with the monthly method EN ISO 13790 and the dynamic simulation tool IDA-ICE. The heat demand of the buildings is calculated using both of the calculation methods and is defined as heat to be delivered to the heated zone by a heating system, so that the set point of heating is reached.

* Corresponding author. Tel.: +358 9 451 3598; fax: +358 9 451 3418.
E-mail address: juha.jokisalo@tkk.fi (J. Jokisalo).

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Heat loss of the zone Q_L is defined as the sum of conduction $Q_{L,c}$ (J) heat loss through the building envelope and heat demand of incoming air $Q_{L,v}$ (J) in the zone

$$Q_L = Q_{L,c} + Q_{L,v} \tag{1}$$

Incoming air is heated by the heating system of the zone (e.g., radiators) to the set point temperature of heating. With the studied mechanical supply and exhaust systems, incoming air is the supply air delivered at supply air temperature.

In the study, all the buildings are assumed to be completely airtight. This is because it is probable that the existing standard EN ISO 13790 overestimates the infiltration air-flow rate compared to the IDA-ICE simulation [6]. In this study, heat losses of infiltration are ignored in order to study purely the effect of the parameters a_0 and τ_0 in the cases that can be calculated as accurately as possible with both of the methods. Besides, a simple calculation method for infiltration air flow is to be removed from the new version of EN ISO 13790. The new version of the standard refers to the other standard, EN 13465 [7], and pre-standard prEN 15242 [8], where more-detailed calculation methods of infiltration air flows are defined.

2.1. The standard EN ISO 13790 [2]

In the monthly method EN ISO 13790, the heat demand of the building Q_h is defined for each calculation period

$$Q_h = Q_L - \eta Q_g \tag{2}$$

where Q_L is the heat loss of the building (J), η the utilisation factor of heat gains and Q_g are the total heat gains, including solar and internal heat gains (J). The annual heat demand is the sum over all the months with a positive heat demand.

$$Q_{h,a} = \sum_{m=1}^{12} Q_{h,m} \tag{3}$$

In the standard, the heat gain and loss ratio γ is defined as follows:

$$\gamma = \frac{Q_g}{Q_L} \tag{4}$$

The time constant of the building is calculated from

$$\tau = \frac{C}{H} \tag{5}$$

where C is the internal heat capacity of building (J/K) and H is the total heat loss coefficient of the building (W/K) caused by transmission and ventilation heat losses. The utilisation factor η for heat gains is defined in the standard

$$\text{If } \gamma \neq 1: \quad \eta = \frac{1-\gamma^a}{1-\gamma^{a+1}} \tag{6}$$

$$\text{If } \gamma = 1: \quad \eta = \frac{a}{a+1} \tag{7}$$

where a is a numerical parameter depending on the time constant of the building τ (h), defined as

$$a = a_0 + \frac{\tau}{\tau_0} \tag{8}$$

where a_0 is numerical parameter and τ_0 reference time constant (h). The standard EN ISO 13790 gives default values for the parameters a_0 and τ_0; for example, for the monthly calculation of continuously heated buildings, the parameters are $a_0 = 1$ and $\tau_0 = 15$ h. The value of these parameters can also be provided at a national level, so the suitability of the default values of a_0 and τ_0 are studied in Finnish conditions.

2.2. The dynamic simulation software IDA-ICE

Dynamic simulations were carried out using IDA Indoor Climate and Energy 3.0 (IDA-ICE) building simulation software. This software allows the modelling of a multi-zone building, HVAC-systems, internal and solar loads, outdoor climate, etc. and provides simultaneous dynamic simulation of heat transfer and air flows. It is a suitable tool for the simulation of thermal comfort, indoor air quality, and energy consumption in complex buildings. A modular simulation application, IDA-ICE, has been developed by the Division of Building Services Engineering, KTH, and the Swedish Institute of Applied Mathematics, ITM [9,10].

IDA-ICE has been tested against measurements [11,12] and several independent inter-model comparisons have been made [13]. In the comparisons, the performance of radiant heating and cooling systems using five simulation programs (CLIM2000, DOE, ESP-r, IDA-ICE and TRNSYS) were compared and IDA-ICE showed a good agreement with the other programs. The tests and the comparisons showed a good justification for selecting IDA-ICE as a reference tool in this study.

2.3. Calculation method of utilisation factor in EN ISO 13790

A correlation-based calculation method for the utilisation factor used by the standards EN 832 [14] and EN ISO 13790 was originally developed in the European PASSYS project at the beginning of the nineties [15]. In that project, the functional shape of the utilisation factor shown in Eqs. (6) and (5) (see Fig. 1) was determined using a curve fitting the monthly points of (η, γ, τ) obtained from calculations of a reference building with different European climates. In the calculations, the glazed area, orientation and thermal inertia of the building were varied and a correlation for Eq. (9) was determined against the reference simulation tool ESP of the PASSYS project.

$$\eta = f(\gamma, \tau) \tag{9}$$

The average European values for the parameters were determined to be $a_0 = 1$ and $\tau_0 = 16$ h for the standard EN 832, and later, for the monthly method of standard EN ISO 13790 and the revised prEN 13790, the values were concluded to be $a_0 = 1$ and $\tau_0 = 15$ h for continuously heated buildings. The effect of thermal inertia of building structures on the utilisation