Energy and Buildings 107 (2015) 68–75

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

# Influence of thermal storage mass on summer thermal stability in a passive wooden house in the Czech Republic

Martin Němeček*, Miloš Kalousek**

*Department of Building Structures, Faculty of Civil Engineering, Brno University of Technology, Veveří 331/95, Brno, Czech Republic*

ARTICLE INFO

*Article history:*
Received 24 February 2015
Received in revised form 26 July 2015
Accepted 29 July 2015
Available online 1 August 2015

*Keywords:*
Summer thermal stability
Sensible heat storage
Thermal storage mass
Numerical simulation
Energy passive house
BSim Software
Wooden houses

ABSTRACT

This article describes the influence of the thermal storage mass of a passive house upon its summer thermal stability during the course of a single day. Summer thermal stability is studied for different construction variants used in passive buildings, both the wooden houses and the brick-built ones. The article deals with sensible heat stored in building materials only. The simulation results for the summer overheating of a passive detached house in Dubňany—Czech Republic are presented. The simulation was performed using the numerical method in BSim software. Based on the relationship between the sensible heat storage of thermal mass in a building and the maximum indoor air temperature, a curve describing the effectiveness of thermal mass in preventing overheating was drawn. The main body of the article analyses with more detail the required quantity of storage mass to be used particularly in wooden houses. The article is concluded by a section focusing on the evaluation of thermal storage in the structural mass of wooden houses.



## 1. Introduction

Energy passive buildings have very low yearly heat consumption [1,2]. For achieving these characteristics they must operate on the principle of solar houses where especially the living areas have large glazed surfaces facing the south or west (Fig. 1) [3]. Large south-facing glazed windows without shading elements can mean more overheating related problems than usual in current buildings [4,5]. The current envelope structures in passive houses with large thermal resistance make only a very minor contribution to their overheating [6]. Although the main cause of the overheating of buildings resides in windows unprotected against sunshine, the size of the thermal mass of a house can have some influence on the thermal stability of its rooms [7]. At present, many more energy-saving family homes are being built on the basis of timber structure in the Czech Republic than before. However, most wooden buildings lack significant thermal storage mass. This is due to their construction system and the techniques used to build them (Fig. 2).

It raises the question of how much building mass is needed to effectively reduce the air temperature inside the house. If a greater quantity of thermal storage mass is really needed in a house than it contains naturally, in what form should it be installed in the interior.

The influence of the storage mass of a house on the maximum indoor air temperature was examined via numerical simulation in BSim software for a passive detached house in Dubňany—Czech Republic. The temperature was examined during one critical summer day. The simulation was based on previous measurements taken at the house which lasted for several days, with the same boundary conditions. Summer thermal stability is studied for different structural variants used in passive buildings, wooden houses and brick-built ones.

## 2. Requirements

According to the Czech standard ČSN 730540-2 2011 [8], the main aspect for evaluation in the summer season is the highest internal air temperature $\theta_{ai,max}$ during the day on 21st August. When evaluating the air temperature of rooms in residential and public buildings in the summer season, the following requirement must be fulfilled:

$$\theta_{ai,max} \leq 27\,^{\circ}C$$

The calculation of summer thermal stability takes place under conditions stipulated by the Czech and European standards [9–11] in which the thermal state is unsettled, with a periodically repeated temperature; this state is illustrated in Fig. 3. The curves for real temperature and global solar radiation are illustrated in Fig. 4.

* Corresponding author. Tel.: +420 54114 8104.
** Corresponding author. Tel.: +420 54114 7440.
*E-mail addresses:* nemecek.m@fce.vutbr.cz (M. Němeček), kalousek.m@fce.vutbr.cz (M. Kalousek).

http://dx.doi.org/10.1016/j.enbuild.2015.07.068
0378-7788/

**Nomenclature**

| | |
|---|---|
| $A$ | area [m$^2$] |
| $c$ | specific thermal capacity [J kg$^{-1}$ K$^{-1}$] |
| – | clothing insulation [clo] |
| $d$ | thickness [mm] |
| $C_{A,\mathrm{eff}}$ | effective areal heat capacity [kJ m$^{-2}$ K$^{-1}$] |
| $C_{R,\mathrm{eff}}$ | total effective heat capacity of the room per floor area [kJ m$^{-2}$ K$^{-1}$] |
| $C_V$ | volumetric heat capacity [MJ m$^{-3}$ K$^{-1}$] |
| $T$ | period [h] |
| $T$ | thermodynamic temperature [K] |
| $U$ | thermal transmittance [W m$^{-2}$ K$^{-1}$] |
| $\theta$ | Celsius temperature [°C] |
| $\Delta\theta$ | Celsius temperature differences [K] |
| $t$ | Celsius temperature [°C] |
| $I$ | intensity of solar radiation [W m$^{-2}$] |
| $\lambda$ | thermal conductivity [W m$^{-1}$ K$^{-1}$] |
| $\pi$ | mathematical constant [–] |
| $\rho$ | bulk density [kg m$^{-3}$] |
| $\delta$ | periodic penetration depth of heat wave in a material [m] |

*Subscript*

| | |
|---|---|
| ai | air, internal |
| max | maximum |
| *e* | exterior |
| op, *o* | operative |
| gl | global |
| rm | running mean |
| *l* | limit |

The Czech standard ČSN EN 15251 specifies the important parameters of the internal environment. Required values for the operative temperature representing thermal comfort are set for category II (new buildings with current expectation of comfort) during summer time for living rooms and offices as follows:

- Mechanically cooled building: maximum operative temperature $\theta_o$ 26.0 °C (clothing 0.5 clo)
- Buildings without mechanical cooling: the highest possible operative temperature according to the formula (including regulation of ventilating, clothing etc.):

$$\theta_{l\,\mathrm{max}} = 0.33\,\theta_{\mathrm{rm}} + 18.8 + 3$$

**Fig. 1.** Typical passive house with large south-facing windows.

**Fig. 2.** Typical timber-framed wooden house.

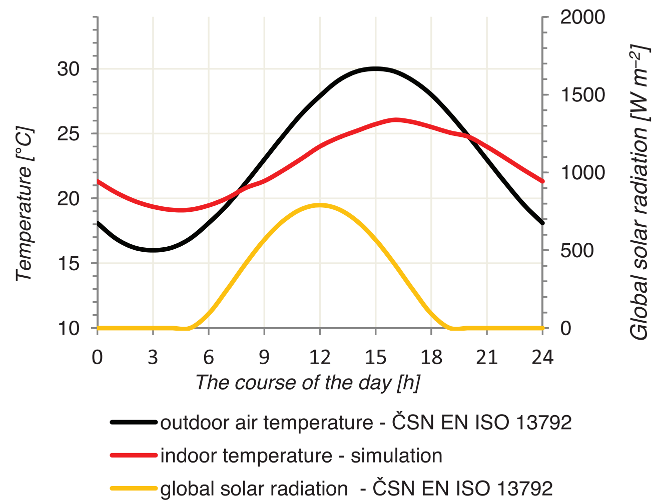


**Fig. 3.** Summer thermal stability according to ČSN EN ISO 13792.

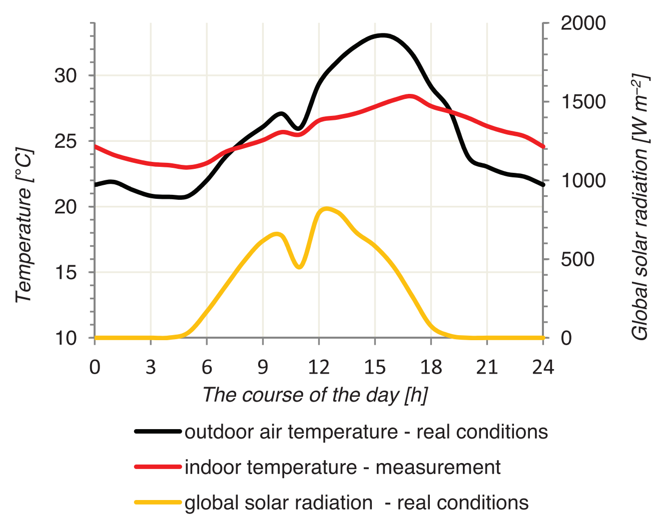


**Fig. 4.** Summer thermal stability—real conditions.