Sustainable Cities and Society 24 (2016) 20–32

Contents lists available at ScienceDirect

Sustainable Cities and Society

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

Simple rule to estimate the changes in the heating demand of the German Passivhaus when accomodating the climate of Eastern Europe

Viorel Badescu[a,e,*], Nicolae Rotar[b], Sanda Budea[c]

[a] Candida Oancea Institute, Polytechnic University of Bucharest, Spl. Independentei 313, Bucharest 060042, Romania
[b] Nuclearelectrica, Str. Polona 65, Bucharest 010494, Romania
[c] Department of Hydraulics, Hydraulic Machinery and Environmental Engineering, Polytechnic University of Bucharest, Spl. Independentei 313, 060042 Bucharest, Romania
[e] Romanian Academy, Calea Victoriei 125, Bucharest, Romania

ARTICLE INFO

Article history:
Received 17 February 2016
Received in revised form 5 April 2016
Accepted 7 April 2016
Available online 8 April 2016

Keywords:
Passivhaus
Technology transfer
Germany
Eastern Europe
Heating demand

ABSTRACT

The *Passivhaus* (PH) concept was developed in the 1990s in Germany. Tens of Passivhauses are now built in Eastern Europe and the technology transfer raises well-known as well as specific problems, related to the difference of climate. Most previous studies about the dependence of the PH heating demand on climate have been performed by using the Koppen-Geiger climate classification. Here a more recent classification based on climate zones and climate types is used. Several tens of localities have been selected, covering all climate zones and types of Germany and two countries of Eastern Europe (Romania and Ukraine). An existing Romanian PH has been defined as a prototype and it has been conceptually moved in all localities. Simulations are performed by using the Passive House Planning Package (PHPP) developed by the Passive House Institute of Darmstadt. For given climate zone and climate type, the PH heating demand clearly depends on latitude, in all three countries. A *linear dependence* between the PH heating demand and latitude may be used in first approximation, and this assumption works better in the climate of Eastern Europe than in Germany. A simple empirical rule is proposed for the estimation of the heating demand of a given PH .

1. Introduction

The *Passivhaus* (PH) concept was developed through a number of research projects performed before year 2000 by the Passive House Institute (PHI) of Darmstadt in Germany. Well supported by good practice in a series of structural and functional applications that gave remarkable results in Germany, the PHI design solutions have established themselves as the standard (PHI, 1997). The interest in the PH standard spread outside Germany in other Central, Western and Nordic European countries, as well as on other continents (Badescu, Rotar, & Udrea, 2015; Sehizadeh & Ge, 2016).

There is a tendency for the PH concept to be assimilated in Eastern Europe, where two PHs were built in Romania in 2004 and 2008 (AMVIC, 2013; Badescu, Laaser, & Crutescu, 2010; Badescu, Laaser, Crutescu, Crutescu, Dobrovicescu et al., 2011), and one PH has been built in Slovenia in 2006 (Mlakar & Štrancar, 2011). Tens of PHs are now built in Eastern Europe (Passive House Database, 2016) and the technology transfer raises well-known issues (Devapriya and Ganesan 2002; Johansson and Turkenburg, 2004; Nelms, Russell, & Lence, 2007; Blomke, 2014) but also specific aspects. One of the problems faced by designers when the PH concept migrated from Germany to Eastern Europe was the climate difference (Badescu et al., 2010; Badescu, Laaser, Crutescu, Crutescu, Dobrovicescu et al., 2011). The climate of Eastern Europe has temperate continental features with harsher winters and hotter summers while Germany's climate has more maritime influences. Lower U-values are needed in case of more severe winters. However, decreasing the U-values yields overheating in summer. This has been already reported in the CEPHEUS project for some regions of Germany and Austria, where 12% of the occupants were less satisfied about the indoor climate in summer (Feist, Peper, & Gorg, 2001). However, the phenomenon is more frequent in Romania (Badescu et al., 2010). As a consequence, the PH performance changes when migrating from Germany to South Eastern Europe (Rotar and Badescu 2011; Badescu and Rotar 2012).

---

* Corresponding author.

E-mail addresses: badescu@theta.termo.pub.ro (V. Badescu), nicolae.rotar@gmail.ro (N. Rotar), sanda.budea@upb.ro (S. Budea).

http://dx.doi.org/10.1016/j.scs.2016.04.005
2210-6707/

The performance of low-energy buildings depends on design and use specifications as well as on climate (Anastaselos, Oxidis, Manoudis, & Papadopoulos, 2016; Cole 2012; Kneifel, Healy, Filliben, & Boyd, 2016; Moreci, Ciulla, & Lo Brano, 2016). Two meteorological parameters that have a direct effect on PH performance, i.e. the ambient temperature and the global solar irradiation, have been analysed in Badescu and Rotar (2012). Results showed that these two parameters have a contrary effect on the level of the heating demand when hypothetically moving a given PH from Germany to Romania. For instance, in Romania the average winter temperature is lower than in Germany and this is associated with a trend for higher heating demand in Romania than in Germany. On the other hand, the winter solar irradiation is higher in Romania than in Germany and this is associated with a trend for lower heating demand in Romania than in Germany. The analysis was extended in the quoted paper to more complex meteorological parameters like sky temperature, dew point temperature and the Ivanov continentality index. The dependence of the PH heating demand on these parameters does not show distinctive features in Germany and Romania, respectively. Climate influence over PH performance were further considered under the framework of the Koppen-Geiger climate classification (Badescu et al., 2015).

Simple models and calibration procedure for the building energy models are very useful for early design (Al Gharably, De Carolis, & Ranjithan, 2016; Samuelson, Ghorayshi, & Reinhart, 2016). Therefore, a more involved analysis of the PH performance is performed in this paper. It is based on the climate classification used more recently in Briggs, Lucas, and Taylor (2002); Briggs et al. (2003a, 2003b). Climate zones and climate types are defined for Germany and two countries of Eastern Europe (Romania and Ukraine). Meteorological, radiometric and heating degree days data have been collected for several tens of localities in these countries. An existing Romanian PH was defined as a prototype and it has been conceptually moved in all localities. Simulations have been performed by using the Passive House Planning Package developed by the PHI (Feist, Puger, Kaufmann, Schnieders, & Kah, 2007). Next, the PH heating demand has been evaluated and classified according with climate type and zone. The dependence of the heating demand on heating degree days and latitude, respectively, is analysed for each climate and type zone. Comparisons between Germany and Eastern European countries are performed. A simple empirical rule is proposed for the estimation of the heating demand of a given PH. The rule works better in Eastern European countries than in Germany.

2. Sample Passivhaus

The sample building considered here is the AMVIC PH located in Bragadiru (latitude 44.4°N), a small town 10 km south of Bucharest, Romania. It is a ground floor and four levels office building inaugurated in February 2009. The structure and the main functions of the building are listed now. On the ground floor there is a wide open space where the sales department and the secretary's office are located. In a separated area there is a service room. The first, second and third floors are wide open office areas. On the top floor there are five apartments. The AMVIC PH may be classified as a "functional *non-residential* Passivhaus". The energy criteria for this type of Passivhaus are: a maximum value of 15 kWh/(m^{2}y) for the heating (or cooling) demand and if not met alternatively the maximum heating power of 10 W/m^2; also, a maximum value of 120 kWh/(m^{2}y) for total primary energy consumption (the sum of all primary demands for heating, domestic hot water, auxiliary and household electricity—including appliances) (Feist, Borsch-Laaks, Werner, Loga, & Ebel, 1998; Passive de, 2013).

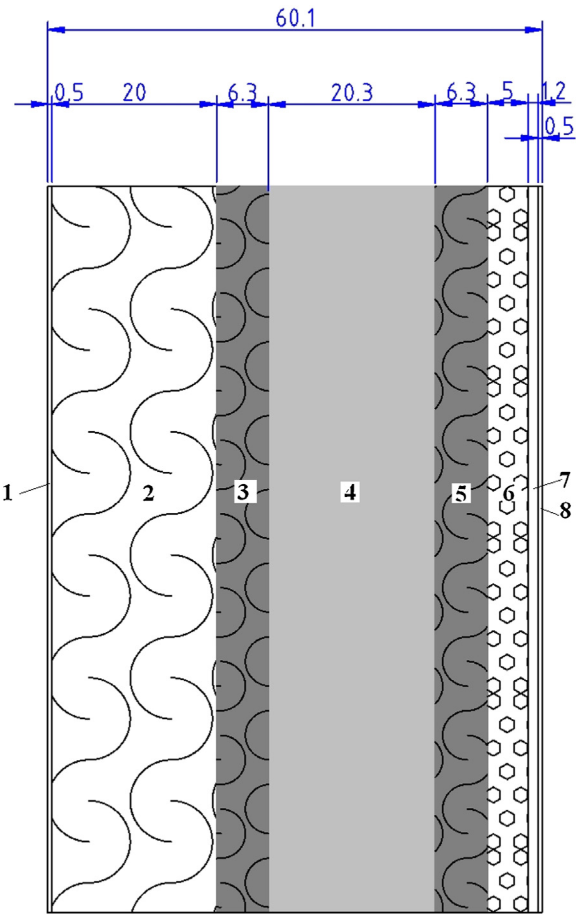

Fig. 1. Structure of the external wall of the AMVIC PH. 1 – Fiber glass mesh – washable painting (thermal conductivity $\lambda = 0.140$ W/(mK)); 2 – Polystyrene (density $\rho = 24$ kg/m^3, $\lambda = 0.040$ W/(mK)); 3 – insulation material #1 ($\rho = 24$ kg/m^3, $\lambda = 0.031$ W/(mK)); 4 – concrete ($\lambda = 2.5$ W/(mK)); 5 – insulation material #1 ($\rho = 24$ kg/m^3, $\lambda = 0.031$ W/(mK)); 6 – insulation material #2 ($\lambda = 0.039$ W/(mK)); 7 – plaster board ($\lambda = 0.250$ W/(mK)); 8 – fiber glass mesh – washable painting ($\lambda = 0.140$ W/(mK)).

AMVIC PH is well documented in Badescu et al. (2010); Badescu, Laaser, Crutescu, Crutescu, Dobrovicescu et al. (2011) and has been monitored for a relatively long time (2009–2013). A few details follow. The heating and ventilation system contains: (1) a registry-type ground heat exchanger; during wintertime, it warms up, while during the summer it cools down, the outdoor incoming air; (2) a high-efficiency heat-recovery heat exchanger built into the ventilation system; during the cold season the outgoing air warms up the incoming fresh air; (3) two water-to-water heat pumps are used to warm up the fresh air incoming the building in the cold season or during bad weather or nights and to cool down the fresh air in summer. The heat reservoir for the heat pumps is the soil beneath the building. The AMVIC building is provided with two other active local heating systems and operational control of the ventilation-heating/cooling system, including the main heater. The building has 75 separation elements with high thermal inertia. These are grouped in external and internal walls, respectively, roof, ground plate and floors, the structure of each separation element depending on its function. Fig. 1 shows the structure of the South external wall, as an example. External walls are provided with low-emissivity triple-pane glazing windows with reduced overall heat transfer coefficient U and high solar transmission factor. Some of the separating elements are provided with doors. More details about the structure of the envelope of the AMVIC PH are