Energy and Buildings 67 (2013) 403–418

Contents lists available at ScienceDirect

Energy and Buildings

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

A new house wall system for residential buildings

Fayez Aldawi[a], Firoz Alam[a,*], Abhijit Date[a], Mohammed Alghamdi[b], Fahad Aldhawi[c]

[a] School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University, Melbourne, Victoria 3083, Australia
[b] Department of Mechanical Engineering, Yanbu Industrial College, Yanbu, Saudi Arabia
[c] Saudi Kayan Petrochemical Company, Al Jubail, Saudi Arabia

ARTICLE INFO

Article history:
Received 18 April 2012
Received in revised form 15 June 2013
Accepted 9 August 2013

Keywords:
New house wall
Brick veneer house
Thermal performance
Greenhouse
Star energy rating
Thermal mass
Insulation material

ABSTRACT

The residential housing sector consumes a significant amount of fossil fuel energy and thereby produces a large percentage of greenhouse gas emissions that contribute to global warming and climate change. At present, approximately 40% of the total household energy used is required for space heating/cooling and a substantial amount of that energy is lost through the house walls. Despite the importance of house walls for energy efficiency, most published literature focuses mainly on thermal comfort, environmental impact and economic costs of residential buildings. Little information is available on energy efficient house wall systems that can be used and adapted for varied climate conditions with minimal design change and associated cost. Therefore, the primary objective of this paper was to undertake a thermal performance study of two house wall systems with single and double glazed windows under variable climate conditions. The study was undertaken using thermal performance simulation software AccuRate®. The findings indicate that a significant energy saving can be achieved using the new house wall system compared to currently used brick veneer house wall system.

1. Introduction

Rapid urbanisation and population growth necessitate the expansion of cities and towns with new buildings and associated energy needs. The residential sector is a great contributor to greenhouse gas emissions (~30%) due to the use of primarily fossil fuel energy (~35–40%) [1]. According to a recently published Australian government report, the energy consumption in the residential housing sector will be around 467 PJ in 2020 compared to 299 PJ in 1990 which means the energy demand will increase by over 50% [1]. The number of residential houses in Australia is expected to be around 10 million in 2020 compared to 6 million in 1990 [2]. The floor space area and volumetric dimension of modern residential houses are increasing at a constant rate in most developed countries including Australia (Fig. 1). Therefore, the energy consumption for heating and cooling is also increasing. Fig. 2 illustrates a continuous upward energy consumption trend in Australian housing sector for coming years [3,4]. The increasing energy consumption leads to greater greenhouse gas emissions.

Fig. 3 shows the top 3 countries (Australia, United States and Canada) generate over 18 tonnes CO_2 emission per capita which is significantly higher than India and China [5]. The Australian per capita CO_2 emission has been contributed largely by the coal based power generation and inefficient use of energy in the housing sector. Among household consumption, around 40% of the total energy is used for space heating and cooling (Fig. 4). Hence, the reduction of energy use for space heating and cooling not only enhances energy conservation, it also reduces greenhouse gas emissions and can enhance energy security [6]. A substantial amount of energy required for heating and cooling is lost through the house wall systems [7].

Despite the importance of house wall systems for energy efficiency, most published literature focuses mainly on thermal comfort, environmental impact and economic cost of residential buildings [8–14]. Gregory et al. [15], Zhu et al. [16], Wakefield and Dowling [17] reported the importance of thermal comfort and thermal masses on energy performance of various building types (brick veneer, double brick and weatherboard walls). Haapio and Viitaniemi [18], Tommerup et al. [19], Börjesson and Gustavsson [20], Damineli et al. [21], Dodoo et al. [22], Van den Heede and De Belie [23] investigated the environmental impact of various house wall systems (e.g., brick veneer, concrete and weatherboard). The importance of various house insulation materials has been reported by Ozel [24] and Bektas Ekici et al. [25], Ballarini and Corrado [26], Budaiwi and Abdou [27], Jelle [28], and Al-Homoud [29]. However, little information is available in the open literature on energy efficient house wall systems made of combined thermal masses and insulation materials that can be used and adapted for variable climate conditions with minimal design changes and cost. Hence, the main objective of this paper is to undertake the thermal

* Corresponding author. Tel.: +61 427980868.
E-mail address: faiz0505@hotmail.com (F. Alam).

0378-7788/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.enbuild.2013.08.019

Nomenclature

h_{in}	convective heat transfer coefficient inside, W/m^2 °C
h_{out}	convective heat transfer coefficient outside, W/m^2 °C
h_{total}	total convective heat transfer coefficient, W/m^2 °C
x	thickness of wall materials, m
x_{total}	total wall thickness, m
$T_{wall.in}$	surface wall temperature inside, °C
$T_{wall.out}$	surface wall temperature outside, °C
$T_{air.in}$	air temperature inside, °C
$T_{air.out}$	air temperature outside, °C
A	wall surface area, m^2
k	material thermal conductivity, W/m °C
K_{total}	total material thermal conductivity, W/m °C
Q_{loss}	heat transfer rate loss, W/m^2
Q_{total}	total heat transfer rate by convection and conduction, W/m^2
Q_{rad}	total heat transfer rate by radiation, W/m^2
σ	Stefan–Boltzmann constant = 5.6703×10^{-8}, W/m^2 K^4
R	thermal resistance of material, °C/W
R_{total}	total thermal resistance of materials, °C/W
β	coefficient of volume expansion, K^{-1}
g	gravity acceleration, m/s^2
δ	characteristic length of wall geometry, m
U	overall heat transfer coefficient, W/m^2 °C
ν	kinematic viscosity of the air, m/s^2
Pr	Prandtl number at certain temperature, –
Ra	Rayleigh number, –
Nu	Nusselt number for vertical plate (wall), –
ε	emissivity of the material, –
A$	Australian dollar, A$

performance study of two house wall systems (one conventional and other new design) with single and double glazed windows for variable climate conditions.

2. Description of house wall systems

There are two types of house wall systems commonly used in Australia: brick veneer and weatherboard house walls. However, the brick veneer house wall system (here on a conventional house wall system) is the most widely used. In this study, we have selected a 3-bedroom house with a conventional house wall system and a new house wall system. The average floor area is 100.2 m^2 and the total physical volume is approximately 460 m^3. The house consists of a living or dining area, kitchen, three bedrooms, two bathrooms and an alfresco. The roof slope angle is kept at 20° as per Building Code of Australia (BCA) [30]. Fig. 5 illustrates a plan view of the house floor area. The breakdown of house flooring area is shown in Table 1.

The orientation of the house is north facing due to Australia's geographical location in the southern hemisphere. The bedrooms and living/dining areas need ongoing heating and cooling. The floor foundation is selected "H class" reinforced concrete slab for reactive clay. The thickness of the concrete slab is 100 mm. Fig. 6 illustrates a typical reinforced concrete floor foundation and a conventional house under construction in Melbourne, Australia.

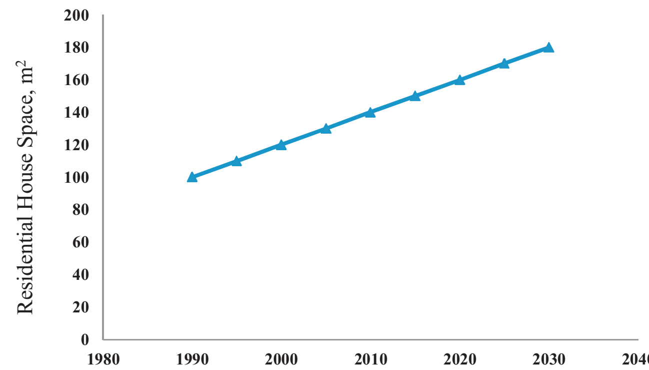

Fig. 1. Average living space in residential houses in Australia [1].

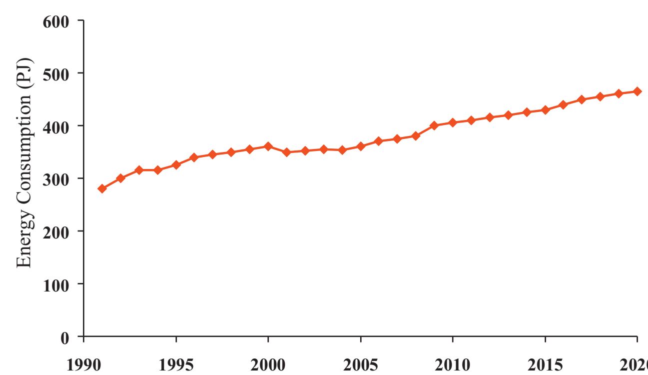

Fig. 2. Energy consumption in Australian housing sector [2].

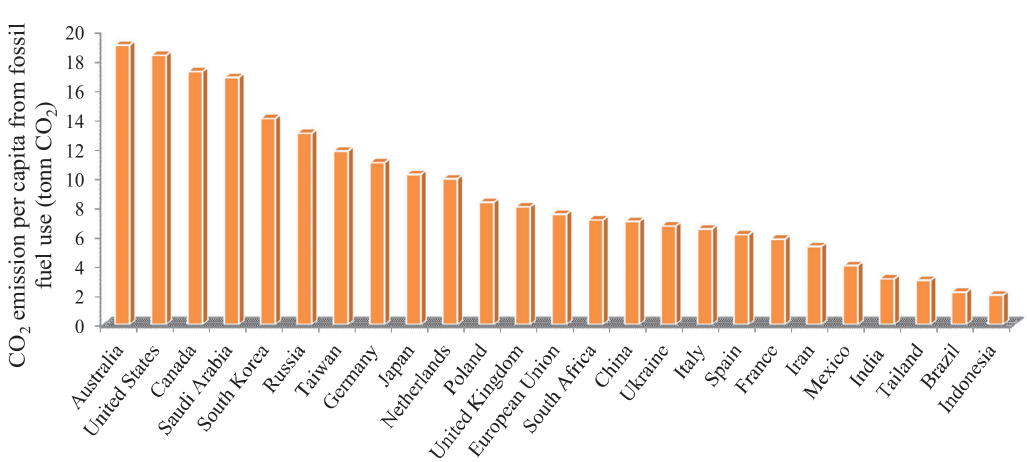

Fig. 3. Greenhouse gas emission per capita from fossil fuel use for selected countries in 2011 [5].