2012 International Conference on Environment Science and Engieering
IPCBEE vol.32(2012) © (2012)IACSIT Press, Singapoore

Investigation on Electricity Consumption Reduction through Foam Lightweight Concrete Utilization in Residential Buildings – Case Study: Tehran, Iran

Hamidreza Kamalan [1+], Samaneh Babaee [2] and Mohammadreza Shabour [3]

[1] Ph.D., Civil and Environmental Engineering, Assistant Professor, Islamic Azad University-Pardis Branch, Tehran, Iran

[2] Ph.D. Candidate, Civil Engineering, Colorado University, Colorado, USA

[3] Ph.D., Civil and Environmental Engineering, Assistant Professor, K.N. Toosi University of Technology, Tehran, Iran

Abstract. Electricity consumption of residential buildings amounts for 33.2% of total electricity demand in Iran. Using proper insulation materials such as Foam Lightweight Concrete (FLC) blocks in houses walls can improve thermal performance of buildings. This paper aims to investigate electricity saving rate of typical Iranian residential buildings as a result of utilizing FLC block walls compared to three common wall materials: pressed brick, terra-cotta block, and 3D panel for two different situations: (i) buildings with constant area and variable heights, and (ii) buildings with constant height and variable areas. Utilizing Behsazan software, the results show that in case one, annual electricity saving through FLC block walls depends on the number of floors and varies from 2.64% to 2.70% and 1.85% to 1.96% in proportion to pressed brick and terra-cotta block walls, respectively. In case two, the saving range, based on the buildings area, is from 2.29% to 3.05% and 1.61% to 2.23% in comparison with pressed brick and terra-cotta block walls, respectively. The difference between electricity consumption of houses simulated by 3D panel and FLC block walls is almost negligible in both situations.

Keywords: Foam lightweight concrete block, electricity consumption, residential building, pressed brick, and terra-cotta block.

1. Introduction

Residential buildings are the large consumers of electricity in many countries. In Iran, residential sector is responsible for 33.2% of total electricity demand [8]. Dissipation of cooling energy through Iranian houses walls is about 15% to 25% [6]. Hence, utilization of wall materials with high thermal insulation properties for residential buildings can result in less demand of electrical energy for cooling purposes.

Foam Lightweight Concrete (FLC) block is an ideal and environmental friendly material in building construction that can reduce both energy consumption and weight of the buildings because of its high thermal resistance characteristic and lightness. Building lightness is critical for Tehran city, a seismic mega-city with more than 12 million residents because weight of buildings will affect remarkably on earthquake forces damages. Besides, energy saving through utilizing appropriate material for building constructions is remarkably important. On these bases, it is critical for future development to know which kind of buildings (high-rise apartment or a house expanded in area rather than height) is less energy consumer.

Most of national researches literature on electricity consumption regarding residential buildings has been focused on reducing electrical energy demand of residential buildings through standardization and energy labeling of household appliances [2]. On this basis, some laboratories have been established in Ministry of

+ Corresponding author. Tel.: +98 912 301 4413; fax: +98 21 2244 3868.
E-mail address: hkamalan@pardisiau.ac.ir

Energy of Iran to test these appliances. According to annual testing results, electrical energy saving attributed to standardization of those equipments stands at about 2420 gWh/year. In another study, electricity consumption of four-story residential building with 720m^2 area in Tehran has been calculated for i) building without thermal insulation material and ii) using 5cm polystyrene insulation in building envelope. It is notable that cooling system in both cases was water cooler. As results show, the former property plays a significant role in raising the total energy consumption of such a big city. Besides, cooling energy consumption can be reduced approximately 11% per annum by inserting thermal insulation in walls and roofs [5].

In a supplementary investigation, cooling energy consumption of a typical house room (6m×4m) has been simulated for three different wall materials such as (i) autoclaved aerated concrete (AAC), (ii) terra-cotta block, and (iii) pressed brick. Electricity saving rate through utilizing AAC block in walls has been compared to terra-cotta block and pressed brick which is equal to 16.3% and 19.6%, respectively [11].

Finally, in a subsequent research [12] the effects of installing six types of double-glazing have been investigated for a typical building in Tehran with 216 m^2 area.

The objective of the present investigation is to evaluate the influence of utilizing four kinds of wall materials (pressed brick, terra-cotta block, 3D panel, and FLC block) on annual electricity consumption of a typical residential building in Iran using Behsazan software in two cases as follow: constant area (470 m^2) and variable heights (5, 10, 13, 17, and 20 floors), and constant height (15 floors) and variable areas (257, 470, 720, 940, and 1240 m^2).

Despite all previous studies, this study focuses mainly on electricity saving of a residential building attributed to utilizing FLC block in comparison with 3 other common wall materials in Iran (pressed brick, terra-cotta, and 3D panel).

2. Materials and methodology

2.1. Materials properties

FLC is a type of porous concrete consisting of macroscopic air voids in size of approximately 0.1 to 1 mm which are uniformly distributed in cement paste. It can be produced everywhere in any shape or building unit size using conventional equipment and machinery. It is cost-effective and simple to be produced [1-13]. By appropriate FLC block production method, wide range of densities (300-1800 kg/m^3) can be obtained. Thus, it offers sufficient flexibility in manufacturing products for specific applications (e.g. thermal and acoustic insulation, and structural and partitioning walls [1-9].

Usage of FLC block in building walls has many advantages. The most important ones are as follow: (i) Utilizing FLC block cause reduction in building dead load and less greenhouse gases emissions out of cement plants, while cement production plants are major contributor to CO_2 emission, (ii) Light and small elements need less transportation fleet which results in less greenhouse gases emission out of transportation vehicles, and (iii) High thermal insulation results in less energy dissipation and of course less consumption and less greenhouse gas emission production [7]. Thermal transmittance which is an important characteristics of wall material for energy saving is defined as the rate of heat flow through a unit surface area of a component with unit temperature difference (1^{o}K) between the surfaces of the two sides of that component. It is also known as U-value and expressed in W/m^{2}K [10]. Low thermal transmittance of FLC block walls is a major contributor to reduction of heat transfer between outside and inside of buildings. Properties of a FLC block wall components material used in this study are indicated in table 1.

Table 1 - Characteristics of FLC block wall components materials [1]

Material	**Density** (kg/m^3)	**FLC block for external wall**		**FLC block for partition wall**	
		Thickness (cm)	**Thermal conductivity** (w/mK)	**Thickness** (cm)	**Thermal conductivity** (w/mK)
Granite stone	2800	2	2.20	-	-
Sand/cement plaster	2100	2	1.15	-	-
FLC block	**	20	0.16	10	0.12
Gypsum plaster	1300	1	0.50	2	0.50
U-value (W/m^{2}K)		**0.682**		**0.915**	

**FLC block density in external and partitioning walls are considered as 800 and 600 kg/m^3, respectively.

A method of calculating thermal transmittance (U-value) of a typical FLC block face wall is presented in equations (1) and (2) [3].

$$R = \sum \frac{X_i}{\lambda_i} \qquad (equ.1)$$

$$U = \frac{1}{R} \qquad (equ.2)$$

Where "R" is the thermal resistance (m2K/W), "U" is thermal transmittance (W/m^{2}K), "Xi" is thickness of the constituent material (m), "λi" is thermal conductivity of the constituent materials (W/mK), and "i" is type of the material of the wall. The values 0.06 and 0.11 m^{2}K/W are thermal resistances of external and internal air filters contacted with wall, respectively [10].

As Babaee et al. Showed, the least thermal transmittance values pertain to FLC block, 3D panel, terra-cotta, and pressed brick walls, respectively. It is clear from tables that only 3D panel partition wall has less value of thermal transmittance than FLC block partition wall [1]. The introduction of stable and unconnected air voids in FLC block wall leads to U-value reduction. Consequently, it improves the thermal resistance of the wall. A thick polystyrene layer in 3D panel wall, which is an appropriate thermal insulation, performs almost the same as FLC block wall in heat transfer reduction through the wall.

2.2. Methodology

To calculate electricity consumption in residential buildings, Behsazan software is utilized. Behsazan, a versatile system design tool for analysis of energy performance in residential buildings, is Visual Basic-based software which provides the user an easy Windows-based graphical user interface [4]. The software has been developed by Energy and Load Management Department affiliated to the Ministry of Energy. Main features of Behsazan software are as follow [1]: implementation of building architectural elements, availability of weather database for 140 cities in Iran, load and energy calculation based on National standard or American Society of Heating, refrigerating and Air-conditioning engineers (ASHRAE) standards, calculation and optimization of building heating, ventilating and air conditioning (HVAC) systems, cooling load calculation using cooling load temperature difference/cooling load factor (CLTD/CLF) method, calculation of lighting systems, domestic hot water, and cold water consumption, as well as cooling and heating energy calculation based on heat load balance and variable base degree-day methods.

As shown in figure 1, the real simulated residential building with the surface area of 470 m^2 has 4 apartments in each floor. In case one, these apartments plan (470 m2 area and 4 apartments in each floor) are constant when the building height varies from 5 to 10, 13, 17, and 20 floors. In case two, building area is changed from 257 to 470, 720, 940, and 1240 m^2. Nonetheless, the building height is constant and it's equal to 15 floors. In addition, the number of apartments in each floor of the building is 2, 4, 6, 8, and 10, respectively. Figure 2 shows the sketch of building plans 257 m^2.

3. Results and discussions

The effects of utilizing FLC block walls compared to the three other wall materials on electricity saving are evaluated for buildings with various heights and areas. The results of Behsazan software output analysis for annual electricity consumption of residential buildings attributed to different wall materials are presented in two following sections based on height and area variations of the buildings.

Electrical appliances, water cooler, and lighting system are the main electricity consumers in the simulated residential buildings. Electrical appliances and lighting system are assumed to be unchanged for all apartments. Hence, the difference in cooling load and electricity consumption is due to different wall materials utilization in residential buildings.

3.1. Electricity Consumption in the Buildings with Constant Area and Variable Heights

Keeping buildings area constant (470 m2) and the heights variable (5, 10, 13, 17, and 20 floors), annual electricity consumption of typical residential buildings simulated by FLC block, pressed brick, terra-cotta block, and 3D panel walls is calculated utilizing Behsazan software as tabulated in Table 2. It shows that annual electricity saving of assumed residential buildings as a result of utilizing FLC block walls (depending on building height) varies from 2.64% to 2.70% and from 1.85% to 1.96% compared to pressed brick and

terra-cotta walls, respectively. This annual saving rate for 3D panel wall is about 0.04% (except for 5-story building which is 0.28%). It is clear that the negligible difference between electricity consumption of the buildings through FLC block and 3D panel walls utilization is due to their close U-value (See tables 2 and 5). The most electricity saving rate through FLC block walls utilization in comparison to pressed-brick, terra-cotta, and 3D panel walls pertaining to five-story building dwelling is about 2.70%, 1.96%, and 0.28%, respectively.

The amount of electricity consumption, as indicated in table 2, ascends along with raising the height of the building that causes enhancement of the area of building envelope and consequently higher heat conduction and cooling load. Besides, the capacity of cooling system increases and it consumes more electricity in order to cool down more apartments in higher elevation. Furthermore, length of installation pipes and consequently their heat convection and air leakage into the conditioned space through them increase. Annual electricity consumption of all 5 buildings (in different heights) is also calculated for $1m^2$ of floor area which is plotted in figure 3.

Electricity consumption curve's trend of the buildings with 3D panel walls is quite fitted to FLC block curve. Also, there is a slight difference between pressed brick and FLC block curves or terra-cotta and FLC block curves which in turn are equal to 2.2 and 1.6 kWh/m2/year. The parabolic curves shapes of electricity consumption and the small coefficients of their equations demonstrate that the variation in buildings electricity consumption for four wall materials is marginal with the number of floors. The least annual electricity consumption of the buildings simulated with FLC block, 3D panel, terra-cotta, and pressed-brick walls is 83.17, 83.40, 84.80, and 85.41 kWh/m^2, respectively. These values are for five-story buildings. However, the most annual electricity consumption through utilizing FLC block, 3D panel, terra-cotta, and pressed-brick walls occurs in thirteen-story house which is equal to 86.72, 86.76, 88.33, and 89.02 kWh/m^2 for four wall materials, respectively.

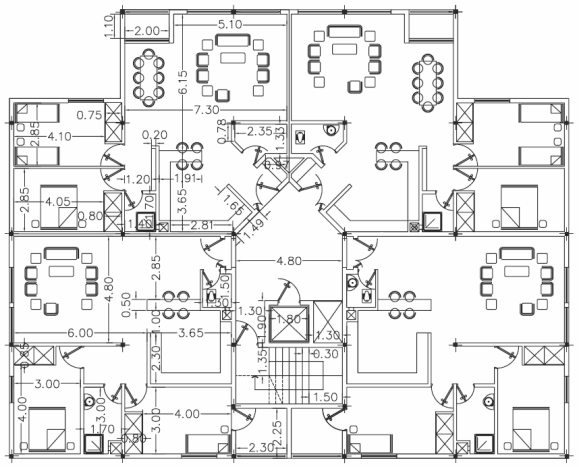

Fig.1 Typical floor plan of simulated residential building (470 m^2)

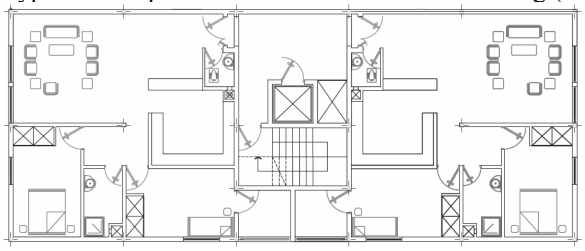

Fig.2 Typical floor plan of simulated residential building (257 m^2)

Table 2 - Annual electricity consumption for residential buildings with various heights and different wall materials

Numbers of floors	Electricity consumption (Megawatt per year)			
	FLC block	Pressed brick	Terra-cotta block	3D panel
5	195.455	200.723	199.293	195.994
10	403.683	414.424	411.211	403.847
13	529.876	543.889	539.694	530.088
17	686.867	705.243	699.737	687.144
20	814.260	835.908	829.420	814.586

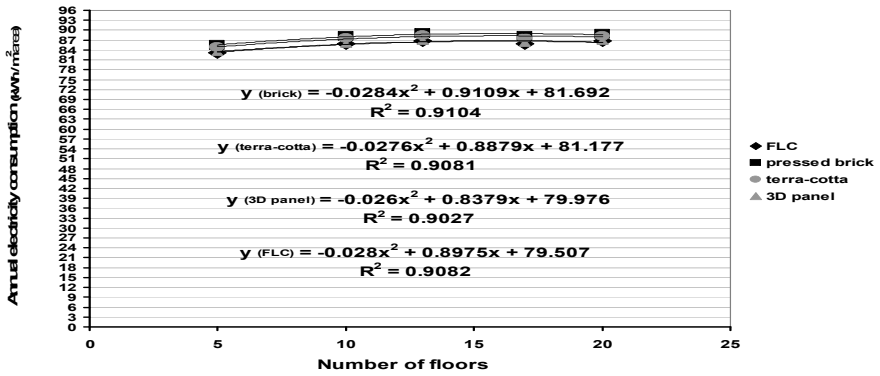

Fig.3 Annual electricity consumption of the residential buildings versus height for various walls materials

4. Conclusions

The use of FLC block in walls can reduce heat transfer between outside and inside of buildings and as a result their electricity consumption decrease. The aim of this investigation is to assess electricity saving rate in Iranian residential buildings through utilizing FLC block walls compared to other common wall materials (pressed brick, terra-cotta block, and 3D panel). Based on numerical results analysis of this study, the following conclusions can be drawn:

i) In residential buildings with constant area and variable heights, annual electricity saving range attributed to utilizing FLC block walls in comparison with pressed brick and terra-cotta walls (depending on the number of floors) is from 2.64% to 2.70% and 1.85% to 1.96%, respectively. Electricity consumption of buildings with FLC block and 3D panel walls is almost the same. Also, the highest electricity saving rate through FLC block walls occurs in five-story houses.

ii) Having constant height and variable areas in residential buildings, annual electricity saving through utilization of FLC block walls (depending on the area of building) varies from 2.29% to 3.05% and from 1.61% to 2.23% compared to pressed brick and terra-cotta walls, respectively. The maximum electricity saving through using FLC block walls pertains to 257 m2 house. Electricity consumption of buildings simulated by 3D panel and FLC block walls is equal. However, in 257m2 houses electricity consumption as a result of utilizing 3D panel walls is 6.5% less than FLC block walls.

To sum it up, utilizing FLC block walls in residential buildings with the lower height (5 stories) and area (250m2) leads to more electricity saving especially compared to traditional wall materials in Iran such as pressed brick and terra-cotta. The primary electricity consumption in Iranian dwelling buildings is related to electrical appliances, while cooling energy dissipation through building envelope is of secondary importance. Considering these two major energy consumptions, electricity saving rate in houses through FLC block walls utilization is not so remarkable and it is limited to 1.6%-3% per year. However, regarding (i) heavy use of electrical power in residential sector, (ii) the exorbitant cost of electricity production, and (iii) respective environmental contamination, even a slight reduction of electricity consumption has a considerable reduction on the expenses and negative environmental impacts reduction.

5. References

[1] Babaee S., Sabour M. R., Kamalan H. (2011). SIMULATION OF NATURAL GAS SAVING THROUGH FOAM LIGHTWEIGHT CONCRETE UTILIZATION IN RESIDENTIAL BUILDINGS, Iran. J. Environ. Health. Sci. Eng., 2011, Vol. 8, No. 4, pp. 333-342

[2] Shirazi, A., (2005). Energy management promotion in Iran. Energy Efficiency Office (EEO), Ministry Of Energy, Tehran, Iran.

[3] Al-Homoud, M.S., (2005). Performance characteristics and practical applications of common building thermal insulation materials. Building and Environment, 40, 353-366.

[4] Behsazan, (2008), Desciription on the Software and the software, available at: www.nri.ac.ir

[5] Fasihi, A., (2006). The effects of using thermal insulation in residential building envelope. Fifth symposium of fuel conservation in building (Tehran).

[6] Ifco, (2008), available at: www.ifco.ir

[7] Kayali, O., (2007). Fly ash lightweight aggregates in high performance concrete. Construction and Building Materials.

[8] MoE, (2007),. Energy statistics and diagrams in Iran and the world (1384, 2005) Iran Ministry of Energy - Energy Planning Office, Tehran.

[9] Narayanan, N., Ramamurthy, K., (2000). Structure and properties of aerated concrete: a review. Cement & Concrete Composites, 22, 321-329.

[10] NationalCode, (2002). Iranian National Building Code (Chapter 19): energy conservation in buildings, second ed. Tose, The office of compiling and developing of Iranian national code, Tehran.

[11] Salehi, M., (2004). Autoclaved Aerated Concrete in energy consumption reduction of buildings. Third symposium of fuel conservation in building (Tehran), 2, 1293-1303.

[12] Soltani, M., Khastoo, B., Bazmara, H., (2006). The effect of glazing type on energy consumption of a typical building in Tehtan. Fifth symposium of fuel conservation in building (Tehran).

[13] Wee, T.H., Babu, D.S., Tamilselvan, T., Lim, H.S., (2006). Air-void system of foamed concrete and its effect on mechanical properties. ACI Materials Journal, 103, 45-52.