Design for Scientific RENAISSANCE

JASER

Energy Saving in buildings in Bahrain: Suitability of Concrete blocks

Article Info

Received: 27/6/2013
Accepted:15/8/ 2013
Published online: 1/9/2013

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ISSN 2231-8844

Abstract

The thermal transmission through of walls and roof in the residential houses more than half of the total peak cooling load. Insulating a building causes a significant reduction in the air-conditioning equipment's capacity in energy consumption, it is possible to save energy by using insulation in the walls and roofs, the type of masonry building materials used for the walls affect heat loss or gain. The objective of this study is to identify the energy saving potentials of different types of blocks used in buildings in Bahrain. The results show that the lightweight concrete blocks with polystyrene insulation have the lowest thermal transmittance U-value and it's the best block available in Bahrain for nonbearing wall structures. The annual savings in energy consumption of buildings constructed using this block is about 30% less compared to the hollow concrete blocks.

Keywords: Energy saving, Energy efficiency, Concrete blocks, Thermal insulation, Thermal material, Thermal transmission, Bahraini materials.

1. INTRODUCTION

Data published by the Electricity & Water Authority of the kingdom of Bahrain shows that domestic buildings consume about 53% of the total electric energy supplied in the country as shown in Fig.1(BMEW, 2005).

Energy is consumed in buildings for air–conditioning, lighting, cooking, cleaning, recreation etc. Reports and studies, conducted in Bahrain, reveal that more than 60 % of energy is consumed by air-conditioning (Mohanadi, 2006).

The excessive demand for air-conditioning has created a need for the design of energy efficient buildings.

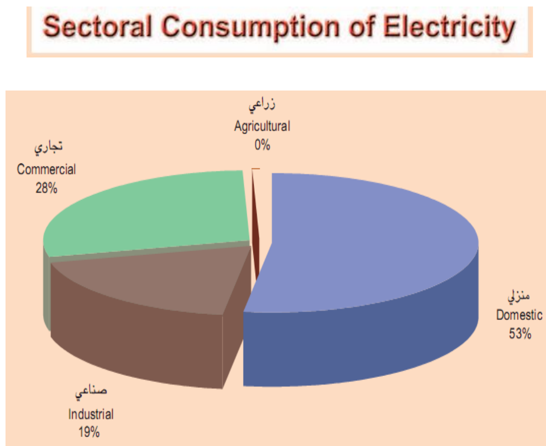


Figure1: Sectorial energy consumption for different sectors in the Kingdom of Bahrain. (BMEW, 2005)

The rate of energy consumption by air-conditioning is influenced by three factors:-

a. Thermal performance of the building, which is affected by a number of factors such as building form, building orientation and glazing surface areas and thermo physical properties of building materials of the envelope of the building.
b. User's behavior in terms of controlling air-conditioning and lighting equipment.
c. General policy of the nation with respect to energy cost and building rules and regulation

Thermal characteristics of a building envelope are among the main criteria, which determine the overall thermal performance. For this reason, a code for thermal insulation is introduced. The code deals with the thermal characteristics of roofs, external walls, and glazed surfaces with the objective of reducing the heat flow through the building envelope. This is done through the limiting of the U-value for the roof and external walls together with defining the type of glass for windows and openings. The use of insulation materials was regarded as the most effective means of reducing the rate of heat transfer from outside to inside during the hot summer, and from the inside to outside during the cold winter.Heat transfer to and from a building takes place through the following elements:-

a. Walls
b. Roofs
c. Ground
d. Infiltration
e. Windows and glazing surfaces.

During the summer, the amount of heat transfer through roofs and walls ranges between 60-70%, as shown in Figure 2 (Ahmad, 2004).

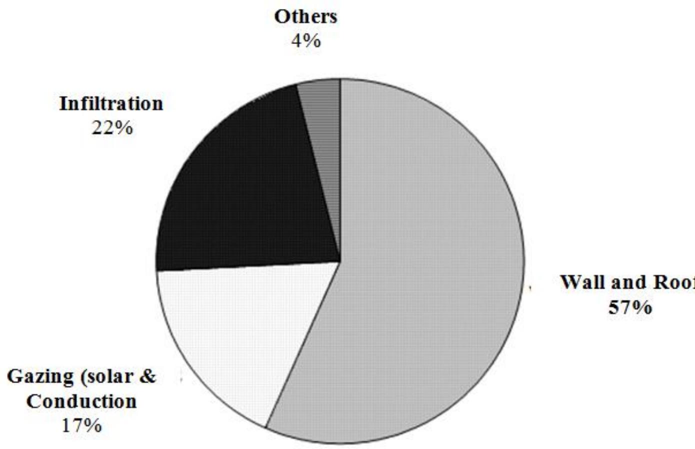


Fig.2: Peak cooling load distribution for residential house (Ahmad, 2004)

This amount of heat should be removed by air-conditioning. Therefore, the use of insulation materials for roofs and walls is essential for energy conservation. These five reducing energy consumption is required in cooling and heating. (Mohanadi, 2006)

Good engineering design of insulation systems will reduce undesirable heat loss or gain by at least 90% in most applications and will often improve environmental conditions at the same time. Consequently, it is highly beneficial to understand insulation theory and applications.

An energy manager must know the different types of insulation available, and their respective advantages and disadvantages in specific applications. Different kinds of insulation are needed for walls and roofs of buildings. Knowing how to perform heat loss-gain calculations is necessary to properly evaluate the effects of adding insulation, and to calculate the benefits of different levels of insulation. (Capehart et al., 2006)

This study compares the thermal transmittance of different types of masonry building block materials available in Bahrain market. It then simulated block material in a study model building to see its effect on energy consumption. Thermal and physical properties of the building materials were taken from the manufacturers and from standard other references.

1. Heat Transfer And The Building Envelope

Heat transfer through a building envelope, (the construction that separates the interior spaces from the outside environment-gain or lose) is influenced by the construction of the outside of the building envelope, along with the wind velocity outside the buildings Each layer of material making up a building's exte**ri**or shell contributes some resistance to the flow of heat into or out of the building.

The amount of resistance depends on the properties and thickness of the materials making up the envelope. Heavy, compact materials usually have less resistance to heat flow than light ones. Each air space separating materials in the building envelope adds resistance as well. The surface inside the building also resists heat flow by holding a film of air along its surface. The rougher surface is the thicker film and the higher the insulation value.

The easiest way to control the transfer of heat through a building envelope is to control heat transfer within the building envelope itself. You can increase thermal resistance by adding insulation or reflective sheets, or by creating more air spaces. The thickness of the air space is not usually critical, but the number of air spaces makes a difference. (Binggeli, 2003).
Heat is always transferred when a temperature difference exists between two bodies. There are three basic modes of heat transfer: Conduction, Convection & Radiation. (Usdoe, 1992)

2. Research Terminologies

The research will use the following terminologies:

2.1. Building Envelope:

Building "envelope" generally refers to those building components that enclose conditioned spaces and through which thermal energy is transferred to or from the outdoor environment. (Turner & Doty, 2007)

2.2. Thermal conductivity (k):

Thermal conductivity is the property of a material, which determines the heat flow by conduction through unit area of the material across unit temperature gradient. Thermal conductivity is influenced by density, water contents and specific heat of the material. In the metric system the unit of measurement is (W/m.ºC). (Mohanadi, 2006)

Conductivity is a measurement of the rate at which heat will flow through a material. High conductance encourages heat transfer between a solid material and air (Binggeli, 2003). The lower k value is the more efficient factor for insulation.

2.3. **Thermal resistance: R-value**:

Under steady-state conditions, the mean temperature difference between two defined surfaces of material or construction that induces unit heat flow through a unit area, in m^2.K/W. and its unit of measurement is m^2.ºC/W (ASHRAE, 2008).

The R-value per inch of a specific material is not necessarily always the same. It can be affected by several factors, including temperature, density, and thickness.

2.4. Thermal transmittance: U-value

The flow rate of heat through a building product is known as the U-value. U-value (or U-factor) is a measure of the flow of heat through a material, given a difference in temperature on either side. In the metric system, it is usually given in Watts per square meter per degree Celsius (W/m2•°C). Since the U-value is a measurement of heat flow, the lower the U- value, the more slowly does the material transfer heat in and out of a house (Bynum & Ebrary, 2001).

As per Bahrain constriction law, the overall thermal transmittance value (U-value) for the walls should not be more than 0.75 W/m^2.ºC. (Mohanadi, 2006)
There is a simple relationship between u- and R-values, normally,
$U= 1/R$ or $R =1/U$.

U-value and R-value are the most common methods used.

2.5. Surface thermal resistance (Rs):

It is the resistance of the thin layer of air close to the surface to heat flow. It is divided into internal surface resistance (Rin) and external surface resistance (Rout). In the metric system the unit of measurement is m².ºC/W.

Surface resistance values in Bahrain are:

(***R***in) = 0.121m².ºC/W.

(***R***out) = 0.059m².ºC/W. (Mohanadi, 2006)

2.6. Total Thermal Resistance (RT):

The total thermal resistance of composite wall is the sum of the separate resistance of the section of in addition to Rs layer. In the metric system, the unit of measurement is m².ºC/W . (Mohanadi, 2006)

3. Calculating Overall Thermal Resistance And Overall Thermal Transmittance:

The research using the calculations methods to calculate the thermal resistance and the thermal transmittance according to the followings:

3.1. Thermal Resistance

The insulating property of a material is generally specified in terms of the thermal resistance (R) of the material, also called the R-value. Thermal resistance is related to the K value as follows. (Capehart, et al., 2006)

$$R = \frac{t}{k}$$

Where t = thickness of material

k = thermal conductivity

To determine the thermal resistance of something composed of several materials, the total thermal resistance (Rtotal) is used. The total resistance to heat flow through a flat building construction composed of parallel layers such as a flat ceiling, floor, or wall (or curved surface if the curvature is small) is the numerical sum of the resistances (R-values) of all layers of the construction in series: R = R1 + R2 + R3 + R4 + … + Rn

Where;

R1, R2,…, Rn = individual resistances of the layers

R = resistance of construction from inside surface to outside surface. However, in buildings, to obtain the overall resistance R_T , the film resistances *R*in and *R*out must be added to R . (ASHRAE, 2008)

R_T = Rin + R + Rout

3.2. Thermal Transmittance

The U-factor (thermal transmittance) is the reciprocal of R_T , or
The insulating property of a material is often measured in terms of conductance rather than resistance. Conductance (U) is the reciprocal of resistance.

$U = \frac{1}{R}$; The overall conductance of a total structure is

$$U\ total = \frac{1}{Rtotal}$$

It is important to note that while the resistances are additive, the conductance's are not. (Capehart, et al., 2006)

3.3. Overall Thermal Resistance and Transmittance of different Types of Building Concrete Blocks Materials in Bahrain

This research selected most of the blocks types which are available and used in the Bahrain market and Bahraini buildings. The Drawings (1 to 5) in Figure 3 are showing the details of each type of block. Thermal Transmittance of Different Types of Masonry Building Blocks in table1. It is taken from the study “The Efficiency of Concrete Block for Domestic Dwellings in Bahrain”. (Nuaimi & Khamis, 2009)

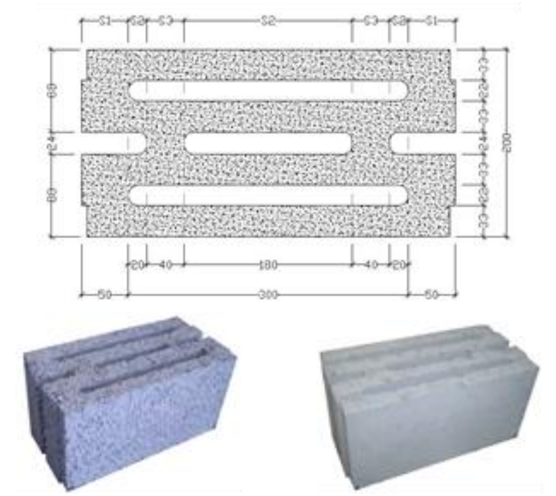
The masonry Building Blocks used in this study:

1. 8" Slotted LW Concrete Block with Air Gap Only
2. 8" Slotted Concrete Block with Air Gap Only
3. 8" Slotted LW Concrete Block with Polystyrene Insulation
4. 8" Slotted Concrete Block with Polystyrene Insulation
5. 8" Hollow LW Concrete Block with Air Gap Only
6. 8" Hollow Concrete Block with Air Gap Only
7. 8" Hollow LW Concrete Block with Polystyrene Insulation
8. 8" Hollow Concrete Block with Polystyrene Insulation
9. 8" Sandwich LW Concrete Block with Polystyrene Insulation
10. 8" Sandwich Concrete Block with Polystyrene Insulation

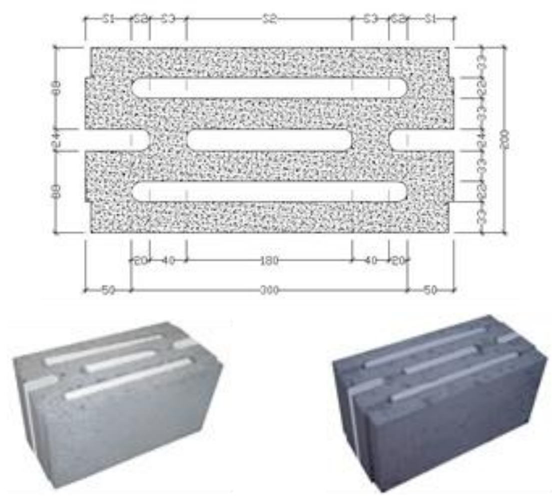
Thermal Properties of the Studied Building Materials

- Thermal Conductivity of Concrete = 1.28 W/m.ºC
- Thermal Conductivity of LW Concrete = 0.21124 W/m.ºC
- Thermal Conductivity of Polystyrene = 0.036 W/m.ºC
- (Rair) Thermal Resistance of Air Cavity space more than 20mm is =0.18 m^2.ºC/W
- (Rin) Thermal Resistance of inside surface = 0.121 m^2.ºC/W
- (Rout) Thermal Resistance of outside surface = 0.059 m^2.ºC/W

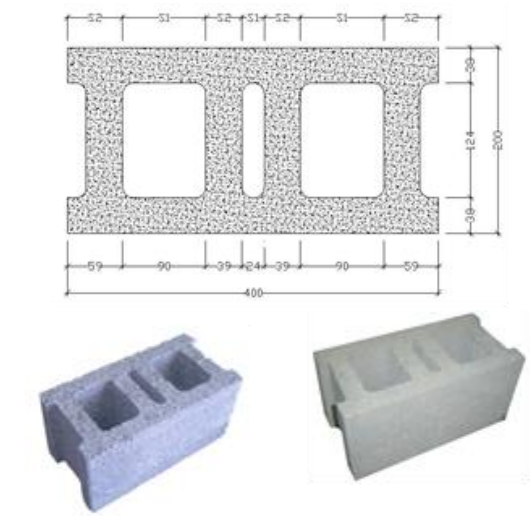
(Rplaster) Thermal Resistance of the plaster = 0.012 m^2.ºC/W



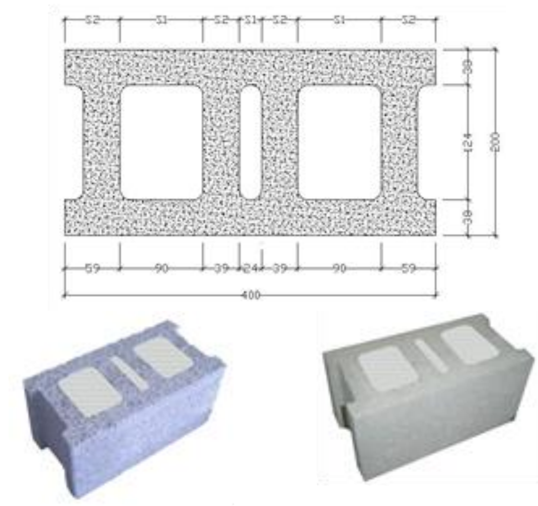
Drawing 1:8" Slotted Block with Air Gap Only



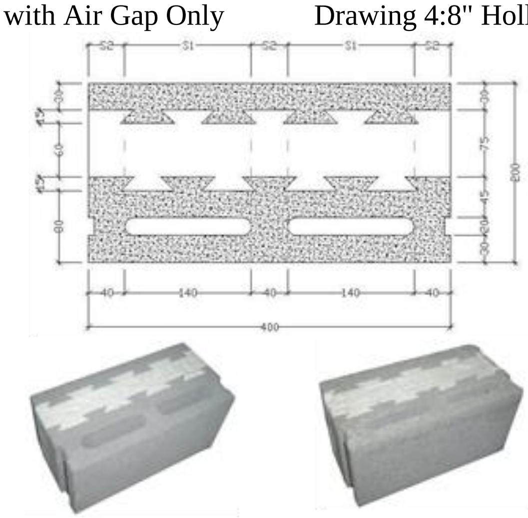
Drawing 2:8" Slotted Block with Polystyrene Insulation



Drawing 3:8" Hollow Block with Air Gap Only



Drawing 4:8" Hollow Block with Polystyrene



Drawing 5:8" Sandwich Block with Polystyrene

Figure 3: Thermal resistance and Thermal Transmittance for different Type of Blocks. (Nuaimi & Khamis, 2009)

Previous details are taken from ASHRAE Handbook of Fundamentals (ASHRAE, 2008), Thermal insulation in buildings (mohanadi, 2006) and from manufacturers' catalogs.The block used in most buildings in Bahrain is the Concrete Hollow Block with air gap only, and in the recent years, people started to use Concrete Hollow Blocks with Polystyrene. Insulation is as per the Ministry of electricity & water requirement. The next pages show the coefficient of blocks to the heat transmittance. The previous equations were used to calculate the overall thermal resistance & overall thermal transmittance for each type of concrete blocks. A simple MS Excel spreadsheet was developed along with this document.

The walls are built with the most common material in Bahrain “8 inch (0.2m) and hollow block” as it was evaluated by Al-Nuaimi and Khamis study (Nuaimi & Khamis, 2009) , by studying the Efficiency of Concrete Block for Domestic Dwellings in Bahrain.

Since we are looking for the highest R-value & the lowest U-value to be used in buildings, we can see in the Table (1) & Figure (4), the differences between each type of block. In (figure 4) the thermal transmittance of the concrete hollow block which is the blocks mostly used in Bahrain is the highest value even when it has the polystyrene insulation, and the lowest thermal transmittance is the sandwich LW concrete block with polystyrene insulation.

Table 1: Thermal Transmittance For different Type of Blocks (Nuaimi & Khamis, 2009).

Type of Blocks	Thermal resistance and Thermal Transmittance for **LECA BLOCK**			Thermal resistance and Thermal Transmittance for **CONCRETE BLOCK**		
	$R_{total\ Block}$ m2 ºC/W	R_{total} m2 ºC/W	U value W/m2 ºC	$R_{total\ Block}$ m2 ºC/W	R_{total} m2 ºC/W	U value W/m2 ºC
8" slotted block with Air gap only	1.1099	1.3219	0.7565	0.4860	0.6980	1.4327
8" slotted block with polysyrene insulation	2.0514	2.2634	0.4418	1.3591	1.5711	0.6365
8" hollow block with Air gap only	0.6838	0.8958	1.1163	0.1899	0.4019	2.4883
8" hollow block with polysyrene insulation	1.5347	1.7467	0.5725	0.3047	0.5167	1.9352
8" sandwich block with polysyrene insulation	2.7342	2.9462	0.3394	2.2935	2.5055	0.3991

4. Simulation Of Energy Consumption

Using an energy Simulation program to evaluate the energy consumption; for different types of concrete blocks in a study model as a residential building.

Building Simulation is widely used for understanding how a building consumes energy and for assessing design strategies aimed at improving building energy efficiency. It is a very useful tool to aid in evaluating the effect of a building envelope material on the energy performance of single family homes.

The energy simulation programs have been effectively utilized in many countries to develop energy codes. These programs are used to evaluate thermal performance of different design alternatives in buildings with energy use.

The major advantage of using a building simulation program is to determine the energy systems and the thermal performance of a building to possibly optimize during the design prose (Capehart, 2007).

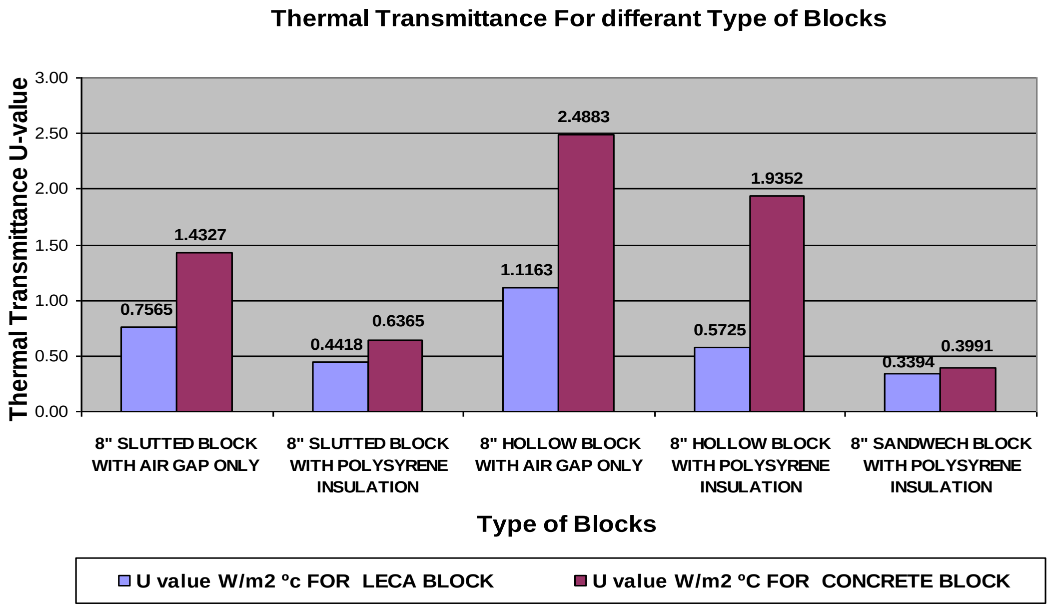


Figure 4: Thermal Transmittance For different Type of Blocks (Nuaimi & Khamis, 2009)

5. eQUEST Simulation Tool

Software tools that combine graphical results with context-sensitive guidance probably have the most appeal for architects. While engineers need software tools that can be used in both the conceptual design phase, when little is known about the building as well as in the final design phases, when most project details have been finalized. The eQUEST program merges simplified input wizards with detailed simulation tools and thus, has potential of meeting the different needs at different stages of the design process (Rallapalli, 2010; Srivastava-Modi, 2011).

eQUEST is a building energy analysis tool that easy is to use with a combining of building creation wizard, an energy efficiency measure is wizard and a graphical display results.

eQUEST is one of the most popular and widely used building energy simulation programs. The reason of this popularity is that it combines basic input wizards with detailed simulation tools and has the potential to meet different needs. Architects, engineers, and researchers can integrate graphical results with context-sensitive guidance. This tool can be used at the conceptual design stage, when little is known about the project, as well at the final design process when most building details have been finalized (Rallapalli, 2010; Srivastava-Modi, 2011).

eQUEST has been selected for this study. It is a very useful tool in the industry, given all its advantages that include ease of use, production of graphical results and more.

6. Base Case Study Model

This study will simulate the thermal performance of the wall with different types of locks for the test model.

The building considered in this study is one single room in a residential house in Bahrain as shown in Figure 5. The layout of the room is 3x3x3 cubic meters. The room consists of all plain walls.

The purpose of selecting the cubic shape for the study model was follows:

- To avoid the effect of building shape on the energy consumption of the interior zone.
- To avoid the effect of orientation of the building.
- The practical height for residential building in Bahrain is 3m, that's why the wall width and length will be 3m.
- Neglecting the interior space function to focus on the effect of wall material.
- Space is without furnishing to Neutralize different variables
- Walls are built with the material most common used in Bahrain "8 inch blocks.
- The ceiling and the floor are made of 6 inch (0.15m) concrete Heavy Wight 140 lbd, the roof without insulation and the floor is connected to the earth.
- The Base case building is located in Bahrain with a total floor area of 9m².
- The building model is consists one zone. Since the building is a residential test model, the operation schedule is 24 hours a day and 7 days a week. The internal temperature for the building is considered to be 24ºC, which is considered as the appropriate temperature for human comfort. Hourly weather data of Bahrain for the years from 1998 to 2010 is used as the weather file required by the simulation program eQuest.
- The building has the dimensions as shown in Figure 5. Which is taken as viewed from eQuest energy simulation tool.

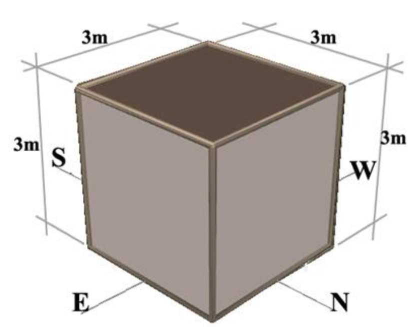


Figure5: Dimensions of the Study Model in perspective view. Researchers

In order to investigate the effect of different types of concrete block materials on energy consumption, the modeled was simulated by using eQuest 3.64 energy simulation program. The simulation was performed using weather data file for the years from 1998 to 2010 for Al-Hidd in Al-Muharaq Bahrain (TMY2). From the web site Weather Analytics Inc. “Precision, On-site Weather Data for Energy Use Profiling, Modeling and Management” [14]

The input data requirement to start the Simulation Programs is described as follows:

1. Weather and geographical data
2. Building physical data, internal loads, and operational characteristics.
3. HVAC system and equipment characteristics.

- The input data of the wall material is the result of the u-value of different types of blocks from the Table 1.
- The base case of the residential building has been modeled using eQuest to evaluate the energy consumption.
- Energy consumption for the base case is evaluated under various wall materials.
- When performed the computer simulations, only one parameter is changed keeping the rest of the parameters at their base-case values.
- The parameter which will be evaluated is the main external walls material.
- In order to evaluate the thermal performance of different wall elements, they should be simulated in a typical residence, other than comparing these systems individually through their R-value. To design the whole house properly, the individual components that affect the building energy performance must be modeled as accurately as possible

7. Results

After run the e-Quest program for the different types of concrete blocks the energy consumption for the virtual built room, the result was as shown in Figure 2. The annual energy consumption of the block material for the building model for Bahrain is presented in Table 3. The table shows that the 8" SANDWECH LECA BLOCK WITH POLYSYRENE INSULATION consumes about 30% less energy, the 8" SANDWECH CONCRETE BLOCK WITH POLYSYRENE INSULATION 29% less energy, 8" SLOTTED LECA BLOCK WITH POLYSYRENE INSULATION 28% less energy, the 8" HOLLOW LECA BLOCK WITH POLYSYRENE INSULATION with 26% less energy than the Base line model 8" HOLLOW CONCRETE BLOCK WITH AIR GAP ONLY. And all other block material simulated consumes between 6% and 25% less energy than the Base line model. While the annual energy consumption and HVAC electric consumption of different type of concrete block as shown in Figure 6.

Table 2: Quest annual building summary report. Researchers

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Annual Energy and Demand (pg 1 of 2)

Annual Energy USE or DEMAND		Ann. Source Energy Total Mbtu	Ann. Source Energy EUI kBtu/sf/yr	Annual Site Energy Elect kWh	Annual Site Energy Nat Gas Therms	Lighting Electric kWh	HVAC Energy Electric kWh	HVAC Energy Nat Gas Therms
0	Base Design	52	524.60	5,124	--	368	3,742	--
1	0+Hollow Lec-block Air	43	429.93	4,199	--	368	2,817	--
2	0+Hollow Con-block Poly	49	491.73	4,803	--	368	3,421	--
3	0+Hollow Lec-block Poly	39	385.88	3,769	--	368	2,387	--
4	0+Slot Con-block Air	45	451.45	4,409	--	368	3,027	--
5	0+Slot Lec-block Air	40	402.52	3,931	--	368	2,550	--
6	0+Slot Con-block Ploy	39	392.61	3,834	--	368	2,453	--
7	0+Slot Lec-block Poly	37	374.71	3,660	--	368	2,278	--
8	0+Sandwich Con-block Ploy	37	370.91	3,623	--	368	2,241	--
9	0+Sandwich Lec-block Poly	37	365.49	3,570	--	368	2,188	--
1	0+Hollow Lec-block Air	9	94.66 (18%)	925 (18%)	--	0 (0%)	925 (25%)	--
2	0+Hollow Con-block Poly	3	32.86 (6%)	321 (6%)	--	0 (0%)	321 (9%)	--
3	0+Hollow Lec-block Poly	14	138.71 (26%)	1,355 (26%)	--	0 (0%)	1,355 (36%)	--
4	0+Slot Con-block Air	7	73.15 (14%)	714 (14%)	--	0 (0%)	714 (19%)	--
5	0+Slot Lec-block Air	12	122.07 (23%)	1,192 (23%)	--	0 (0%)	1,192 (32%)	--
6	0+Slot Con-block Ploy	13	131.99 (25%)	1,289 (25%)	--	0 (0%)	1,289 (34%)	--
7	0+Slot Lec-block Poly	15	149.89 (29%)	1,464 (29%)	--	0 (0%)	1,464 (39%)	--
8	0+Sandwich Con-block Ploy	15	153.69 (29%)	1,501 (29%)	--	0 (0%)	1,501 (40%)	--
9	0+Sandwich Lec-block Poly	16	159.10 (30%)	1,554 (30%)	--	0 (0%)	1,554 (42%)	--

eQUEST 3.64.7130 Annual Building Summary (2 pgs)

Table 3: Annual energy consumption and HVAC electric consumption of different type of concrete blocks. Researchers

Type of Blocks	Total Energy Consumption	% Saving of energy	HVAC Electric kwh	%HVAC Saving
8" HOLLOW CONCRETE BLOCK WITH AIR GAP ONLY	5,123.50	0.0%	3,742	0.0%
8" HOLLOW CONCRETE BLOCK WITH POLYSYRENE INSULATION	4,802.60	6.3%	3,421	9%
8" SLOTTED CONCRETE BLOCK WITH AIR GAP ONLY	4,409.20	13.9%	3,027	19%
8" HOLLOW LECA BLOCK WITH AIR GAP ONLY	4,199.00	18.0%	2,817	25%
8" SLOTTED LECA BLOCK WITH AIR GAP ONLY	3,931.30	23.3%	2,550	32%
8" SLOTTED CONCRETE BLOCK WITH POLYSYRENE INSULATION	3,834.50	25.2%	2,453	34%
8" HOLLOW LECA BLOCK WITH POLYSYRENE INSULATION	3,768.80	26.4%	2,387	36%
8" SLOTTED LECA BLOCK WITH POLYSYRENE INSULATION	3,659.60	28.6%	2,278	39%
8" SANDWECH CONCRETE BLOCK WITH POLYSYRENE INSULATION	3,622.50	29.3%	2,241	40%
8" SANDWECH LECA BLOCK WITH POLYSYRENE INSULATION	3,569.60	30.3%	2,188	42%

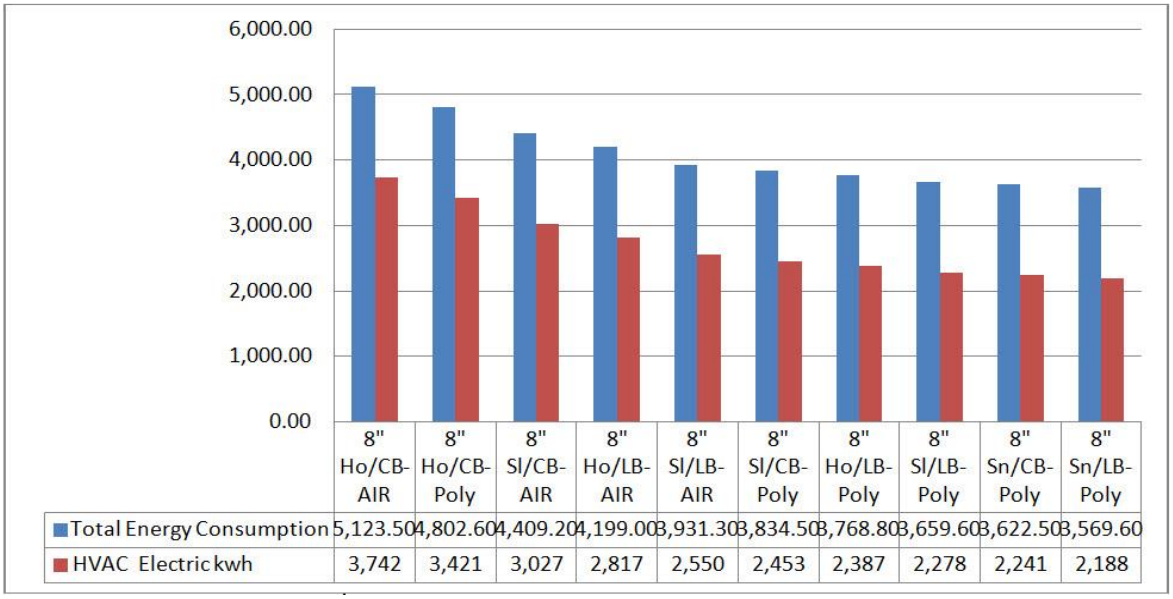

Figure 6: The annual energy consumption and HVAC electric consumption of different type of concrete blocks. Researchers

As Air-conditioning and ventilation take the largest part of energy consumption, table 3, shows this saving in HVAC When comparing different types of blocks. The 8" SANDWECH LECA BLOCK WITH POLYSYRENE INSULATION saves (about 42%. The 8" SANDWECH CONCRETE BLOCK WITH POLYSYRENE INSULATION saves (about 42%. The 8" SLOTTED LECA BLOCK WITH POLYSYRENE INSULATION SAVE 39%.less than the 8" HOLLOW CONCRETE BLOCK WITH AIR GAP ONLY.

8. Result Analysis

As it shows in the previous Tables, saving of energy is between10% to 42% for different types of blocks.

The monthly energy consumption of finishing material for the building model is shown in Table 4 and Figure 7. The Figure shows the range of energy consumption in different months. It is clear that for many months in the year the energy consumption for the summer period (from May to October) is higher in terms of using air-condition. Therefore more saving in energy will be in these months.

Table 4: Monthly Energy Consumption of the study model for different type of Blocks. Researchers

Type of Blocks	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
8" Ho/CB-AIR	206.1	195.7	299.4	368	502.5	608.2	649.4	655.3	568.1	491.8	337.5	241.5	5,123.50
8" Ho/CB-Poly	193.1	182.6	281	344.7	470.4	569.7	608.8	614.8	532.3	460.5	317.4	227.3	4,802.60
8" Sl/CB-AIR	180	168.6	258	314.4	428.3	522.9	559.5	566.3	488.5	419.6	291.9	211	4,409.10
8" Ho/LB-AIR	171.9	160.3	246.1	299.4	407.2	496.9	532.2	539.4	464.8	399.2	279.4	202.3	4,199.00
8" Sl/LB-AIR	162.4	149.9	230.1	280.2	380.3	463.8	497.5	505.3	434.9	373.4	263.4	190.2	3,931.30
8" Sl/CB-Poly	159.3	146.8	224.1	273.1	370.5	451.8	484.9	493	424.1	363.9	257.5	185.4	3,834.40
8" Ho/LB-Poly	157.6	145.1	219.8	268	363.4	443.9	476.6	484.9	416.9	357.1	253.1	182.4	3,768.80
8" Sl/LB-Poly	154.7	142	212.8	260	352.4	430.2	462.2	470.9	404.6	346.5	246.7	176.7	3,659.60
8" Sn/CB-Poly	153.7	141.1	210.3	257.2	348.6	425.5	457.3	466.1	400.4	342.9	244.6	174.7	3,622.50
8" Sn/LB-Poly	152.4	139.8	206.8	253.1	343.3	418.9	450.4	459.3	394.5	337.8	241.4	172	3,569.60
Total	1691.2	1571.9	2388.4	2918.1	3966.9	4831.8	5178.8	5255.3	4529.1	3892.7	2732.9	1963.5	40920.4

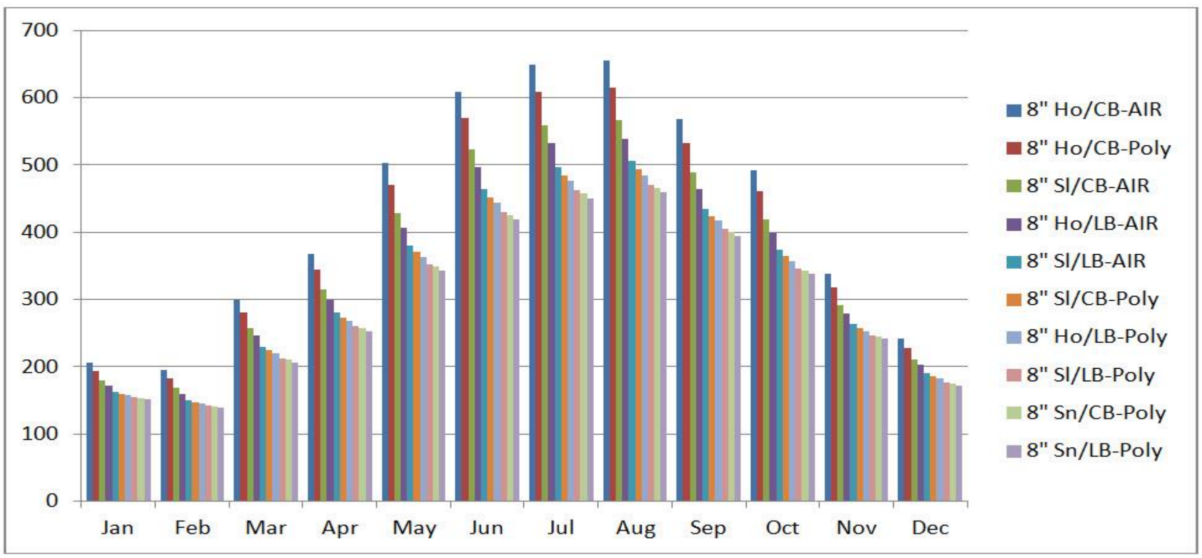

Figure7. Monthly Energy Consumption of the study model for different type of Concrete Blocks

9. Conclusion

The results show that the lightweight concrete block with polystyrene insulation (sandwich block). Have the lowest Thermal Transmittance U-value (0.34 W/m²°C) and it's the best block available in Bahrain for non-bearing walls structure.

The simulation result shows that the saving in the total energy consumption is 30% and in HVAC electric saving is 42% in comparison to 8" hollow concrete block with air gap only.
Most houses in Bahrain are constructed with the concrete hollow block with air only or with polystyrene which have the highest U-value (2.4883 W/m²°C)-(1.9352W/m²°C) & three times more than what are suggested by the ministry of electricity & water in Bahrain, for the insulated walls (0.75 W/m²°C).

Even when using the insulation in the 8" hollow concrete blocks the saving will be only 6% in the total energy consumption and 10% in the HVAC electric saving.
The lightweight concrete blocks are better than normal concrete blocks for the thermal resistance in all type of blocks.

The slotted block is better than the hollow blocks in energy saving. So using the sandwich lightweight block will reduce the heat loss or gain for the houses in Bahrain & will reduce energy consumption.

References

Ahmad, A. (Oct2004). Energy simulation for a typical house built with different types of masonry building materials. *The Arabian Journal for Science and Engineering, Vol-29*(No.2B), pp.113-126.

ASHRAE. (2008). *2008 ASHRAE handbook heating, ventilating, and air-conditioning systems and equipment*. Atlanta, Ga.: ASHRAE.

Binggeli, C. (2003). *Building systems for interior designers*. New York: J. Wiley & Sons.

BMEW. (2005). *Statistical book 2005*: Bahrain Ministry of Electricity & Water

Bsi. (1997). Building components and building elements - Thermal resistance and thermal transmittance - Calculation method. *British standards -all series*-(6946), ALL. this refrence is not refrence

Bynum, R. T., & Ebrary, I. (2001). *Insulation handbook*. New York: McGraw-Hill.

Capehart, B. L. (Ed.) (2007) Encyclopedia of energy engineering and technology (Vols. 1). Boca Raton, FL: CRC Press.

Capehart, B. L., Turner, W. C., & Kennedy, W. J. (2006). *Guide to energy management* (5th ed ed.). Lilburn, GA: Fairmont Press ; Distributed by CRC/Taylor & Francis.

Inc, W. A. (2012). weather data. 2012, from http://www.weatheranalytics.com/index.html (CAN WE REPLACE THIS REFRENCE)

Mohanadi, K. k. A. (2006). *Thermal insulation in buildings* (1st ed.). Kingdom of Bahrain: Ministry of electricity & water.

Nuaimi, S. F. A., & Khamis, K. (2009). The Efficiency of Concrete Block for Domestic Dwellings in Bahrain. *Gulf University Journal Vol-1*(No.1), pp.119-139.

Rallapalli, H. S. (2010). *A Comparison of EnergyPlus and eQUEST Whole Building Energy Simulation Results for a Medium Sized Office Building.* Unpublished MS, ARIZONA STATE UNIVERSITY.

Srivastava-Modi, S. (2011). *Evaluating the Ability of eQUEST Software to Simulate Low-energy Buildings in a Cold Climatic Region.* Unpublished Master.

Turner, W. C., & Doty, S. (2007). *Energy management handbook* (6th ed ed.). Lilburn, GA: Fairmont Press ; Distributed by CRC Press/Taylor & Francis.