Sixth International Conference on Construction in the 21st Century (CITC-VI)
"Construction Challenges in the New Decade"
July 5-7, 2011, Kuala Lumpur, Malaysia

Air-conditioning Energy Consumption Analysis in Malaysian Residential Buildings

Mohammadreza Kasraei
Universiti Teknologi Malaysia, Skudai, Johor, Malaysia, samkasra@yahoo.com

Dr.Abdul Kadir Marsono
Universiti Teknologi Malaysia, Skudai, Johor, Malaysia, marsono@utm.my

Behzad Hamidi, Masoud navazandeh Sajoudi,Mehdi Nourbakhsh
Universiti Teknologi Malaysia, Skudai, Johor, Malaysia

Abstract

The usage of residential electrical appliances for the last two decades has increased rapidly in Malaysia together with the increasing income per capita. Like other developing countries with hot and humid climates, Malaysia has been experiencing dramatic growth in the number and use of air conditioners, and the usage will be higher in the future. So, energy efficiency is one of the most important issues that be faced in Malaysia. The purpose of this study is to analyze air-conditioning energy consumption based on external walls in residential building sectors within the Malaysian construction industry. The study has been done by specifying twenty four masonry wall alternatives and then, air-conditioning energy consumption for each wall panel was calculated by modeling and simulating the selected case study. The results of the study illustrate that, highly dense insulated materials have the best function in terms of saving energy. After those low density insulation and air cavity wall panels have the second rank, while single layer materials are the worst. For each subgroup, double materials have a better function in comparison to single ones. Among brick, concrete and hollow concrete blocks as the main materials used in this case, hollow concrete blocks have the best function when compares to others. The results of this study have a crucial effect on selecting the optimum external walls in Malaysian residential construction projects.

Keywords

Energy efficiency, energy consumption, modeling and simulation

1. Introduction

Malaysia is one of the most important and developed countries among the Association of Southeast Asian Nations (ASEAN) members. The successful accomplishment of the Industrialization Plan in 1985 (Jomo, 2003) has set forth rapid economic growth and structural transformation away from an agricultural-based economy. The key future challenges facing Malaysia are the rapid growth in fuel demand and costs that will require a large amount of imports to meet the final energy demand in 2020, coupled with the potential significant increase in GHG emissions. In the Ninth Malaysia Plan, the energy demand is estimated to increase at the rate of 6.3% annually (Malaysia Energy Centre, 2006) to sustain the nation's economic growth.

Electricity is a necessity in our daily life as it provides power for lighting, electrical appliances, space conditioning, and water heating. In Malaysia, residential energy use accounts for more than 14,365 GWh or 19% of the total electricity used in Peninsular Malaysia in the year 2006 (Energy Commissions, 2006). The household electricity consumption is very much dependent on the family size, living habits, age number of electrical appliances and usage time. A study was carried out to estimate the average electricity consumption for three different categories in the household. They are the low cost house with average spending of approximately MYR65 per month, medium cost house spending about MYR110 per month and for bungalow spending up to MYR350 per month. The cost of energy used by various appliances in Malaysia is shown in Fig. 1 (Taha FM, 2000).

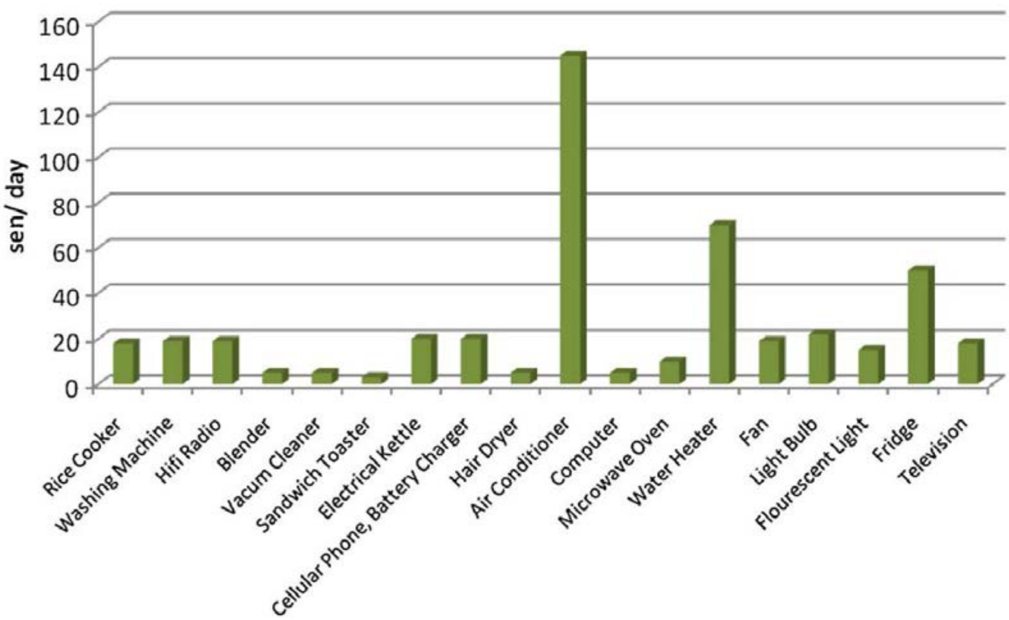

Figure 1: Estimated daily electricity cost per day of various domestic appliances

Therefore, any efficiency improvement of these appliances will produce a significant amount of electricity consumption in the residential sector. The Malaysian government has developed key policies and strategies for over 30 years to ensure energy security as well as sustainability, and encouraged energy efficiency and mitigating environmental impact to meet its rising energy demand. Malaysia's current focus is on developing effective instruments and programs that will facilitate the public and private sectors to adapt energy efficiency (EE) and renewable energy (RE) and to contribute toward energy efficiency as well as environmental sustainability (Zainuddin Abdul Manan *et al*, 2010).

The purpose of this study is to compare air-conditioning energy consumption by analyzing external walls in the residential building sector within the Malaysian construction industry by modeling and simulating a case study.

2. Survey data

2.1 Alternative Specification

Wall alternative selection was focused on three main masonry materials which are found and used easily in different parts of Malaysia. These materials are brick, concrete and hollow concrete. For brick walls, normal clay brick, for concrete walls, concrete brick and for hollow concrete walls, cinder concrete block were assumed. Each one was sub-categorized into two main shapes which are single layer and double layer material and also for each group, there are four finishing shapes which are simple plaster, with air cavity, low dense insulated and high dense insulated. As a result, there are eight alternatives for each material and a totally of twenty four results.

2.2 Thermal Properties Analysis

As the purpose of the study is resource consumption, thermal properties analysis has played role in these calculations. The thermal properties table was prepared for each panel alternative which includes thickness, density, specific heat and thermal conductivity. These property's items were found out for each layer separately and then by putting the results into the table to Autodesk Ecotect® software and creating the element, the software analyzes the whole wall thermal properties and calculates R-value and U-value which are the most important items in the calculation of energy wastage.

3. Methodology

Energy usage cost in each year is one of the most important cost items which are used in the life cycle cost calculation. The calculation was done by modeling and simulating the case study.

3.1 Case Study

Since the scope of this study focused on the residential sector in Malaysia, the case study is a residential building. The case study is a single floor terrace house with four rooms. The location is Sri pulai neighbour in Skudai Johor. The house has three bedrooms, store, WC, bathroom, hall and kitchen in the middle of the house. The height of the ceiling is 3 m except for the kitchen which is 6 m. Materials which were used in the house are single layer brick plaster for the walls, clay tile for the roof and timber frame with single glaze for the windows.

3.2 Energy Consumption calculation

The Autodesk Ecotect software is one of the famous in calculating and analyzing the energies in buildings. In this study energy consumption for different alternatives were calculated and analyzed with this software. The process of modeling the case study and getting results is briefly explained step by step as follows:

- 3D modeling of case: 3D model was shaped by using Ecotect's tools, however Ecotect is able to import 3D models from other software. The process was continued by drawing different zones and locating windows, doors, voids and also roof. Then correct materials were introduced to each part of the building.

- Zone management: In this part by using the zone management tool in Ecotect, functions and specifications for each zone were introduced separately. Each zone contained the air- conditioning type, fuel type, total hour usage a day, the function of the zone such as residential or official, ventilation and internal design conditions.

- Element creating: This part was for introducing wall alternatives in software. This matter was done by using the element library tool in Ecotect. The thermal properties tables which had been prepared were inputted for each wall element alternatives and new elements were created this way.

- Selecting weather location: For starting the analysis, weather location should be chosen. In this software due to a lack of default weather locations, the location which was Johor Bahru, was introduced to software. In this step by using Ecotect's weather tool all information about temperature (low, average and high), humidity, ventilation and rainfall during the year were input. The relevant data was based on the Senai weather station.

Table 1: Monthly electricity usage for air-conditioning

Monthly Electricity Usage for Air Conditioning

Name	Resource consumption (Watt)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
Brick													
Brick Plaster	370550	721609	1111589	1480472	1855520	2212362	2580045	2951088	3317183	3701567	4072464	4449373	**4449373**
Brick Cavity Timber Frame	342830	667544	1029028	1372162	1720970	2052711	2394362	2739328	3079300	3436008	3779392	4127995	**4127995**
Bick Plaster-insulated(low dense)	299918	583955	901642	1205337	1513843	1806973	2108610	2413612	2713540	3027625	3328480	3633242	**3633242**
Brick Plaster-insulated(High dense)	286551	558033	862390	1154222	1450524	1731923	2021426	2314397	2602239	2903253	3190911	3481992	**3481992**
Double Brick plaster	347489	676628	1042907	1390390	1743638	2079626	2425677	2775048	3119422	3480795	3828809	4182171	**4182171**
Double Brick Cavity plaster	331061	644601	994044	1326342	1664102	1985263	2315937	2649924	2978883	3323898	3655625	3992214	**3992214**
Double Brick-insulated(low dense)	298480	581161	897397	1199793	1506966	1798818	2099130	2402816	2701423	3014090	3313522	3616814	**3616814**
Double Brick-insulated(High dense)	275912	537451	830990	1112852	1398922	1670541	1949940	2232828	2510630	2800918	3077964	3358153	**3358153**
Concrete													
Concrete Plaster	381577	743118	1144440	1523577	1909076	2275910	2653954	3035380	3411875	3807270	4189107	4577274	**4577274**
Concrete Cavity Timber Frame	347818	677276	1043652	1390854	1743658	2079260	2425010	2774109	3118391	3479738	3827909	4181524	**4181524**
Concrete Plaster-insulated(low dense)	300303	584704	902786	1206846	1515726	1809215	2111222	2416593	2716887	3031362	3332601	3637758	**3637758**
Concrete Plaster-insulated(High dense)	290199	565108	873203	1168482	1468315	1753084	2046070	2342519	2633829	2938540	3229848	3524668	**3524668**
Double Concrete plaster	351146	683867	1053729	1404060	1760255	2099152	2448230	2800560	3147949	3512580	3864065	4221140	**4221140**
Double Concrete Cavity plaster	337860	657856	1014282	1352899	1697113	2024450	2361523	2701911	3037274	3389081	3727558	4071096	**4071096**
Double Concrete-insulated(low dense)	299584	583306	900661	1204068	1512280	1805127	2106470	2411180	2710812	3024575	3325101	3629521	**3629521**
Double Concrete-insulated(High dense)	278182	541851	837699	1121674	1409915	1683608	1965150	2250171	2530103	2822675	3101988	3384507	**3384507**
Concrete Block													
Concrete Block Plaster	345175	672123	1035982	1381197	1732094	2065837	2409582	2756656	3098772	3457764	3803449	4154433	**4154433**
Concrete Block Cavity Timber Frame	329082	640770	987992	1317961	1653222	1972013	2300306	2631944	2958702	3301446	3631079	3965589	**3965589**
Concrete Block Plaster-insulated(low dense)	298348	580908	896979	1199184	1506154	1797814	2097932	2401425	2699857	3012354	3311644	3614801	**3614801**
Concrete Block Plaster-insulated(High dense)	286120	557273	861305	1152826	1448763	1729907	2019205	2311904	2599440	2900056	3187290	3477917	**3477917**
Double Concrete Block plaster	323090	629066	970290	1295096	1625186	1939013	2262100	2588501	2909896	3246897	3570687	3899124	**3899124**
Double Concrete Block Cavity plaster	309197	602120	929376	1241636	1558865	1860420	2170832	2484540	2793179	3116492	3426556	3740800	**3740800**
Double Concrete Block-insulated(low dense)	296186	576710	890606	1190867	1495842	1785586	2083721	2385243	2681697	2992068	3289221	3590168	**3590168**
Double Concrete Block-insulated(High dense)	275627	536895	830123	1111684	1397444	1668770	1947866	2230454	2507961	2797940	3074692	3354587	**3354587**

- Resource consumption calculation: After finishing previous steps, the software was ready to calculate resource consumption. So the full air-conditioning electricity usage for each year was calculated based on each alternative wall panel.

4. Resource Consumption Analysis

This part is accomplished by using the Autodesk Ecotect® software. Full air-conditioning electricity usage was calculated for the case study. The model was recalculated and reanalyzed by replacing each wall panel alternative to the model which output different amount of electricity usage.

Table 1 has shown all alternatives by classification and their yearly electricity usage divided into different months. As it has been shown in this table, the cumulative energy consumption month to month was calculated and the last column showed total yearly electricity usage. In the brick group the total electricity usage for air-conditioning when using brick plaster wall is 4449373 watt, Brick Cavity Timber Frame 4127995 watt, Bick Plaster insulated (low dense) 3633242 watt, Brick Plaster-insulated (High dense) 3481992 watt, Double Brick plaster 4182171 watt, Double Brick Cavity plaster 3992214 watt, Double Brick-insulated (low dense) 3616814 watt and for Double Brick-insulated (High dense) is 3358153. The yearly energy usage for concrete walls is, Concrete Plaster 4577274 watt, Concrete Cavity Timber Frame 4181524 watt, Concrete Plaster-insulated (low dense) 3637758 watt, Concrete Plaster-insulated (High dense) 3524668 watt, Double Concrete plaster 4221140 watt, Double Concrete Cavity plaster 4071096 watt, Double Concrete-insulated (low dense) 3629521 watt and 3384507 watt for Double Concrete insulated (High dense). And the last part the for hollow concrete block wall panels yearly electricity consumption was, Concrete Block Plaster 4154433 watt, Concrete Block Cavity Timber Frame 3965589 watt, Concrete Block Plaster-insulated (low dense) 3614801 watt, Concrete Block Plaster-insulated (High dense) 3477917 watt, Double Concrete Block plaster 3899124 watt, Double Concrete Block Cavity plasters 3740800 watt, Double Concrete Block-insulated (low dense) 3590168 watt and Double Concrete Block-insulated (High dense) is 3354587.

For better understanding of productivity of each wall panel alternative in energy efficiency, Figure 2 has illustrated each wall panel’s electricity usage by rank. According to this chart double concrete block-insulated (high dense) is the best alternative for energy saving and after that double brick-insulated (high dense) and double concrete-insulated (high dense). At the end of the chart, concrete plaster is the worst. Brick plaster and double concrete plaster are located before. Generally, all high density insulated materials are located in the first parts of the chart and after those; there are low dense insulated panels. In term of thicknesses of walls, double layer walls have a better function in compare of single ones. And also normal plastered walls are located at the end of the chart.

5. Conclusion

Modeling and simulating a case study is the best way to find and calculate resource consumption for different alternatives. In this study, after modeling the building, which is the single floor house, all data about the panel thermal properties which had been found out, was inserted. Next, each alternative resource consumption was analyzed. The results have shown that all high density insulated materials have the best function in terms of energy saving, and after those low density insulated ones. Single layer materials are the worst ones while; air cavity wall panels are in the middle. For each subgroup, double materials have a better function when compared to single layer ones. Between brick, concrete and hollow concrete block as the main materials used in this case, hollow concrete block has a best function in comparison to the others. And also, brick is better than concrete. The reason for this behavior is the lower thermal conductivity in hollow concrete. This matter can cause total U-value of the wall to decrease.

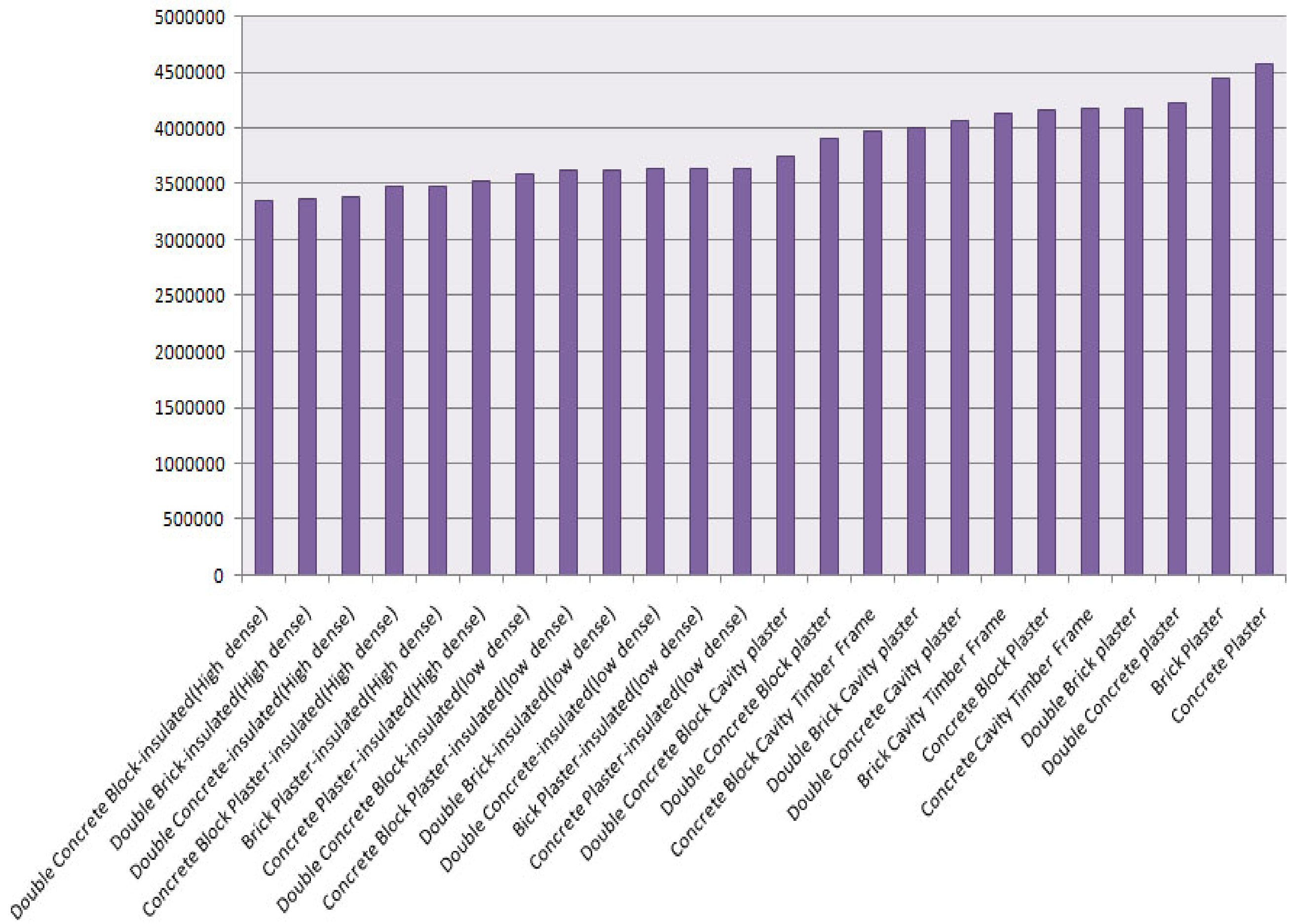

Figure 2: Yearly electricity usage for air-conditioning by rank

6. References

Energy Commissions. Electricity supply industry in Malaysia, performance and statistical information. Kuala Lumpur, Malaysia; 2006.

Jomo, K.S., 2003. Mahathir's Economy Legacy. Vinlin Press Sdn Bhd, Kuala Lumpur.

National Energy Balances 2006 for Malaysia, 2008 by Malaysia Energy Centre (PTM).

Taha FM. Development of energy labeling in Malaysia; past, present and future. Malaysia: Universiti Teknologi; 2000.

T.M.I. Mahlia, P. C. (2011). Life cycle cost analysis of fuel cell based cogeneration system for residential application in Malaysia. *Elsevier, Renewable and Sustainable Energy Reviews* , 416.

Zainuddin Abdul Manan, L. J. (2010). Energy Efficiency Award system in Malaysia for energy sustainability. *Renewable and Sustainable Energy Reviews* , 2279.