Interaction between Theory and Practice in Civil Engineering and Construction
Edited by Komurlu, R., Gurgun, A. P., Singh, A., and Yazdani, S.

ISBN: 978-0-9960437-2-4

COMPARATIVE STUDY OF ENERGY CONSUMPTION FOR AIR CONDITIONING BETWEEN RESIDENTIAL BUILDINGS WITH TWO DIFFERENT SUBFLOORING SYSTEMS

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Energy consumed by heating, ventilation and air conditioning account for about 40% of the total energy used in an average Australian home. The main feature that categorizes the construction systems is the thermal mass as it contributes directly to the thermal performance of the entire house. High thermal mass flooring and walls are most appropriate in climate with high diurnal (day-night) temperature ranges. High thermal mass construction system has higher embodied energy but this can offset by reducing heating and cooling energy consumption over the life span of the house. The optimum design, in terms of desirable heat gain or loss, can be achieved by considering the building orientation, thermal mass and careful design of the building envelope including roof, walls, windows and floor systems. To demonstrate relative advantage in terms of energy conservation between houses with different construction systems and thermal mass, two model houses which are detached dwelling with a floor area of 200 sqm and with two levels and four bedrooms were selected in this study. One of the model houses represented modern house with brick veneer walls and concrete slab-on-ground flooring (high thermal mass Model). The second model house represented old house with fibro walls and raised subfloor (low thermal mass Model). The analysis has been carried out using computer software (IDA ICE). The energy performance of the buildings were computed and compared. The results show that the modern house consumed 53% less energy compared to old house and hence the former is significantly cost effective over the long run.

Keywords: Subflooring system, Thermal mass, Heating and cooling of residential buildings, Stack effect.

1 INTRODUCTION AND BACKGROUND

Households account for 26% of the total energy consumed in Australia and is increasing by 2.6% per year (ABS 2006). In NSW, 88% of residential dwellings use some form of heating systems. The principle systems implemented involved reverse air-conditioning (27%), electric resistance heating (25%) and gas heating (23%). Similarly, different types of air conditioning are in use in approximately half of NSW houses for cooling (ABS 2006).

Design of the house with correct orientation is a fundamental step as passive solar design can reduce the energy demand for heating and cooling. Northern oriented dwelling in Australia could use the solar radiation during winter to reduce heating requirement, while in summer solar radiation can be blocked to prevent unwanted heat. Along with passive solar design, building optimization can be the most important step in providing the house with thermal comfort. Increasing insulations, better performing windows design, heat recovery from ventilation and internal air movement are parts of building optimization.

Many studies have been exploring the energy requirements for the residential buildings, through either computer simulation or field studies considering different parameters. In previous studies different scenarios have been investigated in attempt to reduce the energy consumption through building optimization (Hasan *et al.* 2008, Bambrook 2009, Bambrook 2011). Hasan *et al.* (2008) considered five design variables in both building and HVAC system to minimize the life cycle cost. Three of the variables were continuous which the additional insulation is in the external wall, roof and floor, while the other two were discrete variables which are the U-value of the windows and the type of heat recovery. Bambrook (2009) and Bambrook *et al.* (2011) optimized the building materials using different scenarios to the point where simulated energy requirement for the air conditioning is at the minimum value. However, the models for the studies previously mentioned considered the entire building as a single zone. This will affect the final results of the simulation as the internal air movement between the different zones and levels where not included in the analysis. Also, these studies did not include occupants' number and behaviors in the analysis.

The purpose of this paper is to identify the difference in energy consumption between a modern house with brick veneer walls and concrete slab-on ground flooring and an old house with fibro walls and floating timber floor which is raised 1 m above the ground level. This paper uses a holistic system approach whereby the dwelling is considered as a complete unit with multi-zones.

Comparison between the two different house scenarios was investigated using computer software (IDA ICE). IDA ICE is a whole year detailed dynamic multi-zone simulation program for the study of indoor climate of individual zones as well as energy requirements of an entire building. IDA ICE can simultaneously perform assessment of all fundamental issues related to the design of a building: envelope, glazing, HVAC system, windows and shadings, occupant's behaviour, etc...

Table 1. Models specification.

Parameters	**Modern House**	**Old House**
Floor	Concrete slab on ground	Timber raised floor
Roof	Terracotta roof	Fibro Roof sheeting
Walls	Brick veneer	Fibro walls
Windows	Double glazing	Single glazing

IDA ICE is delivered in two editions: standard and expert edition. In this study, expert edition has been used to perform the energy loads. The accuracy of the IDA ICE was validated according to CEN13791 (Kropf and Zweifel 2001). This simulation program (IDA ICE) is used to measure the space heating and cooling requirements of a 200 m^2 house. The Sydney weather data for the simulation was obtained from

American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) database (IDA ICE 2014). Both houses were oriented towards the north to maximize the heat gain during the cold season. This applies to countries located to the south of the equator otherwise houses should face south if they are located above the equator The main differences between the two model houses are given in Table 1.

2 ODERN HOUSE (BRICK VENEER WALLS- CONCRETE SLAB ON GROUND FLOOR)

The parameters on this model have considered using standard building materials (Wilkie 2011) used widely in the industry. Brick veneer-concrete slab on ground was used during the simulation. Main living room with high window to wall ratio was oriented towards the north. This allows maximum heat gain during winter and avoids the heat gain during summer. Gyprock internal walls with light insulation were utilized. Double glazing windows were considered and finally the roof materials considered were terracotta tiles.

Modern House was built as a multi-zones model. With two different floors connected through a stair case, it is very important to simulate the stack effect between the two floors. This was also considered during the simulation. Occupants' behaviors were also set during the whole week throughout the year (occupants are out of the house from 8:00 to 15:00 then half of the occupants were considered inside the house from 15:00 to 17:00 during weekdays and all occupants are considered inside the house during weekends). The simulation was done for both heating and cooling requirements.

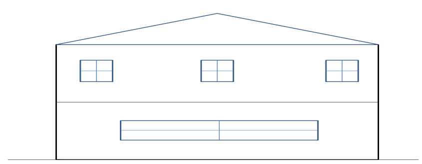

Figure 1. Model house 1.

Air conditioning energy requirement for the Modern House shown in Figure 1 was obtained using the computer model (IDA ICE). The total energy requirement for heating and cooling are also presented in Table 2.

3 OLD HOUSE (FIRBRO HOUSE- RAISED SUBFLOOR)

Standard building materials were used to simulate the model shown in Figure 2. The main key factors were the floating ground floor of the house and the materials used for walls and roof as identified in Table 1. The floor is raised 1 m above the ground. The space between ground level and the ground floor of the house was considered as an open zone in the simulation, which is open to atmosphere. The temperature in this zone was always maintained at ambient levels. This will enable the software to simulate the effect of the outside air movement into the house through the floor and analyze the effect of this air movement on the energy consumption of the house. Timber flooring system was implemented for the floors. Fibro flat sheets are used for models walls and ceilings with thickness of 6 mm and 4.5 mm, respectively (NSW Government 2015). Main living room with high window to wall ratio was oriented towards the north to gain heat in the winter and control solar radiation in summer. Ground and first floors were connected with a staircase. Buoyancy effect was also considered during the simulation of the model to ensure realistic conditions. Occupants' behaviors were also set during the whole week as described in Section 2.

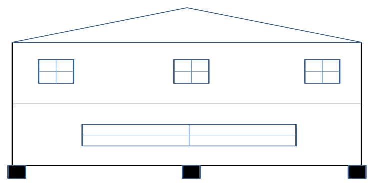

Figure 2. Model house 2.

Energy requirements, as generated by the computer software IDA ICE, for heating and cooling of the model house are shown in Table 2.

4 DISCUSSION OF RESULTS

The results of the annual energy consumption for heating and cooling have been produced in kWh/yr and kWh/(yr.m^2) as shown in Table2. The modeling results indicate that the energy required for heating and cooling of Modern House was 53% less than the energy required for Old House. The annual total energy for Modern House was 10,658 kWh/yr while it was 19,956 kWh/yr for the Old House as shown in Figure 3.

The above results show the considerable differences in the energy requirement for heating and cooling between the modern and old houses. The old houses, in Australia, were built about 40 to 50 years ago. Currently, almost all of the houses built are modern houses. Thus, it can be said that the current houses are far superior to the old houses in terms of energy conservation.

Table 2. Total delivered energy.

	Modern House		**Old House**	
System description	kWh/yr	kWh/(yr/m^2)	kWh/yr	kWh/(yr/m^2)
Electric cooling	9866	24.66	15508	38.77
Electric heating	792	1.98	4448	11.12
Total	10658	26.64	19956	49.89

The results indicate that the modern houses with brick veneer walls and concrete slab on ground flooring are more efficient in energy saving compared to the old house with fibro walls and timber subfloor system. Energy savings over the typical life span of the building of 50 yr period can be significantly high for the modern house. This energy saving works out to be 464,900kWh Based on the average energy tariffs in

NSW, which is AUS $0.278/kWh, the net present value (NPV) of the cost savings over 50 yr works out to be $47,482 . This amount is calculated using an interest rate of 5%. In addition to this cost saving, the energy saving achieved in the case of Modern House will have positive environmental effects, particularly, in terms of reduced greenhouse gas emissions.

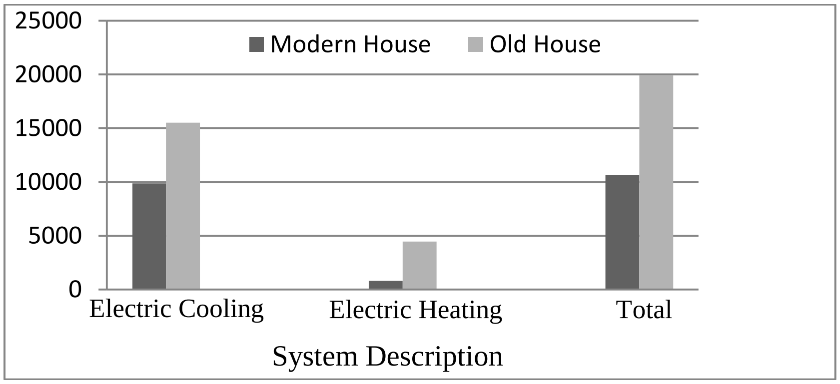

Figure 3. Total energy consumption.

Acknowledgements

Authors express sincere gratitude to School of computing, Engineering and Mathematics IT team, particularly Mr. Keith Rynott and Mr. Rocqueforte O'Leary, for their assistance in installing the software. Also, our thanks are due to EQUA Simulation AB, Sweden, specifically, Ms. Jenny Sjostrom for providing technical support in relation to use of the software.

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