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ENERGY STAR RATING OF A TRADITIONAL AND INNOVATIVE RESIDENTIAL HOUSE

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Abstract- *One of the largest energy consumers is the residential household throughout world and subsequently the sector produce a large percentage of greenhouse gas emission. The overall impact of the residential housing energy and materials consumption on global warming potential, ozone depletion, nitrification and acidification potential is significant. The ultra-energy efficient residential house envelopes utilising optimal thermal mass and insulation ensuring occupant comfort, energy savings and good indoor air quality and will not only reduce ongoing energy bills but also reduce consumption of fossil fuel and greenhouse gas emission. The paper describes thermal performances of a traditional and innovative house wall system for two climatic zones (moderate and arid climates). The energy performance has been evaluated using an Australia wide accredited energy performance simulation software AccuRate. The simulated results indicate a significant improvement in terms of energy savings of the new house wall system compared to the traditional house wall system. A notable reduction of greenhouse gas emission can also be achieved based on the simulated results.*

Keywords: Conventional house, Innovative house, Star energy rating, Thermal performance, Global warming.

1. INTRODUCTION

The rapid expansion of cities, suburbs and growth of the population worldwide over years has led to huge the demand on residential buildings in developed countries as well as in developed countries. The expanding population increases the demand for new buildings and houses as a result there are huge energy needs. Around 30% of global warming comes from building construction and dwelling processes. Heating and cooling consumes approximately 40% of the total energy at the residential sector, (see Figure 1). Nevertheless, in modern residential houses, energy consumption will increase further as the floor space area is progressively expanding as shown in Figure 2. Therefore, many researchers have focused on energy by improving house construction systems using various materials and methods for varied climatic zones. (Alam and Theos [3], Alam et al. [1-3], Kordjamshidi and King[10], Zmeureanu et al. [11], Chen et al. [12] and Zhu et al. [13]).

In Australia, the CO_2 emission and energy consumption for heating and cooling from the residential house sector has significantly increased over the past decade and will continue in the foreseeable future.

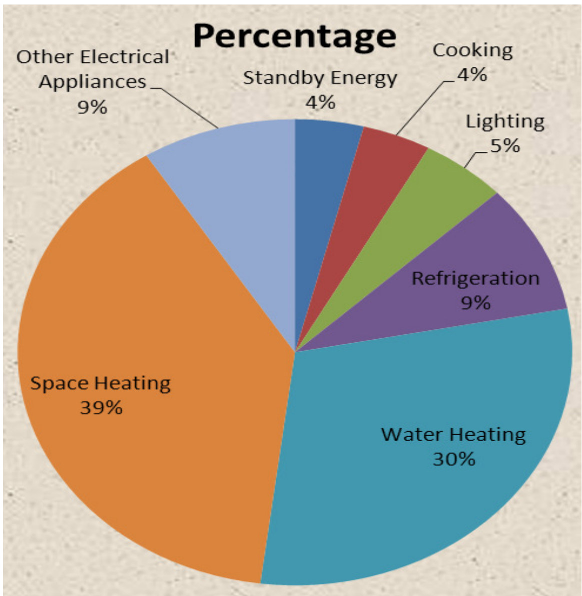


Fig. 1: Residential household energy use in Australia in 2007, adapted from [7]

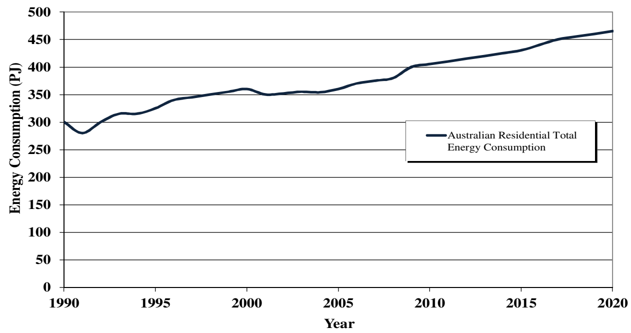


Fig. 2: The increment average of house space, adapted from [7,16]

Although several studies by Alam et al. [1-2], Chen et al. [12] and Zhu et al. [14] have been undertaken on sustainable house construction system using various smart materials, a huge knowledge gap does exist in our understanding of residential continuing energy performance. This is mainly due to varied climate conditions as heating and cooling energy loads largely depend on ambient conditions especially temperature, humidity and solar radiation. Therefore, the primary objective of this paper is to simulate house energy performance of a typical and smart house wall systems construction for two climatic zones: moderate and arid climate.

Moreover, some factors must be taken into consideration in order to reduce energy consumption. The governments of many nations including Australia has initiated various policies, regulations and guidelines which can be summarized as follows:

- Develop higher building construction standards and methods to minimize energy consumption and improve thermal energy performance.
- Find and implement alternative ways to reduce the energy consumption through introducing energy rating systems to estimate residential ongoing energy consumption.
- Utilisation of various computational tools including widely accepted and reliable energy simulation software to estimate the ongoing heating and cooling need for specific geographical location.
- Introduce smart construction materials that have higher heat transfer resistance by maintaining suitable indoor environments with less energy consumption.
- Provide incentives through tax credit and or subsidies for alternative energy use, especially solar and wind energy.

2. METHODOLOGY

2.1 Description of Simulated House

The house selected for the study is a standard 3 bedroom house with an approximate total floor area of 161.33 m^2 and the total physical volume is around 460 m^3. The house consists of a living area, dining area, kitchen, three bedrooms, two bathrooms, an alfresco area and a laundry. The roof slope is around 20 degrees, a widely used roof inclination angle for most houses built in Australia and it is made of timber structure with concrete tiles. The foundation (footing) is standard and the roof (H) class concrete slabs, H mean: highly reactive clay site with high ground movement and a trench full of concrete. The windows are standard size with single glass and aluminum frame. Furthermore detailed description about the wall systems of the conventional and alternative is given in the next sub-sections. The conventional and the alternative wall systems will be simulated in two climatic zones. These zones are Melbourne and Alice Springs. The Melbourne weather is considered to be moderate climate while the weather for Alice Springs is considered arid climate. Figure 3 illustrates the plan view of the house used in this study.

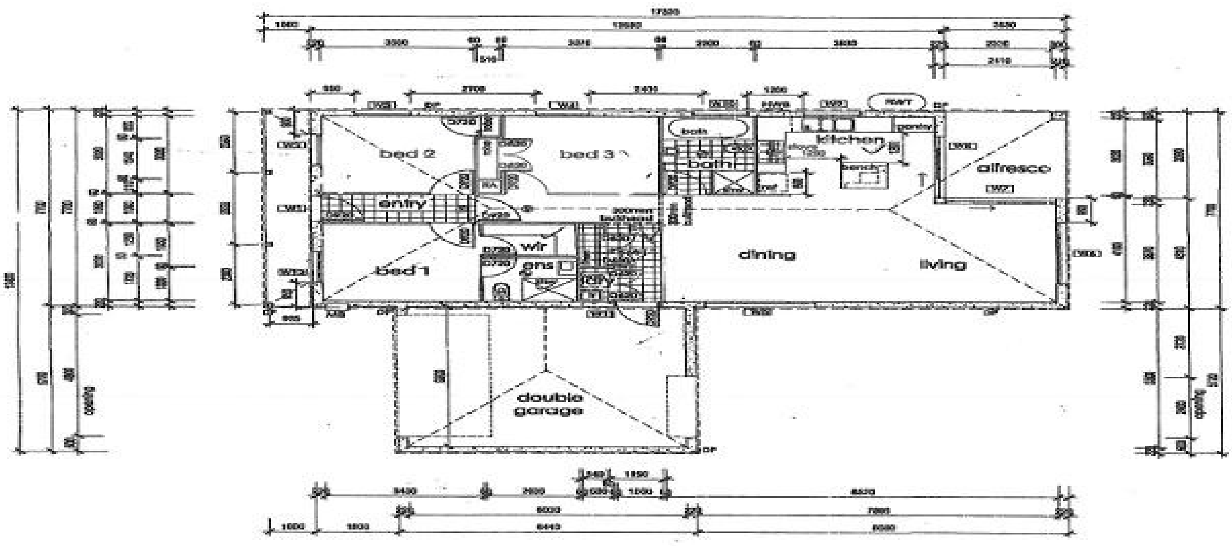


Fig. 3: House plan view

2.2 Simulation Software

Around the world, there are many house energy simulation software packages have been developed. However, this software cannot be used for all climatic zones due to the unavailability of data for local climate, construction materials, and house design. In Australia, the most commonly used simulation software accredited by all States is the AccuRate software. It was developed by the Commonwealth Scientific and Industrial Research Organization (CSIRO). It is widely used for the simulation of the ongoing house energy performance. It provides the house energy need for ongoing heating and cooling at a scale rating of 1 to 10; the higher the star rating the better for energy saving. More about this software can be found in [9]. It has in-built local climatic data for 69 climatic zones across Australia.

The software contains all the functions and features of heat transfer equations that are required for all 3 modes of heat transfer (conduction, convection and radiation). It also incorporates the effects of natural ventilation in the house energy rating. Further information about 'Accurate' software will be seen in Section 4.

3. HOUSE CONSTRUCTION MATERIALS

3.1 Materials of conventional residential houses

In general, the conventional Australian residential house consists of foundation (concrete slab or timber stamp), roof ceiling and wall systems (brick veneer, timber frame, plasterboard). Details of the house wall system are described later for both conventional houses but with energy saving innovations. The roof system consists of flat plasterboard ceiling and inclined roof structures with tiles and/or corrugated iron sheets. Figure 4 shows the conventional residential house's pictorial views.

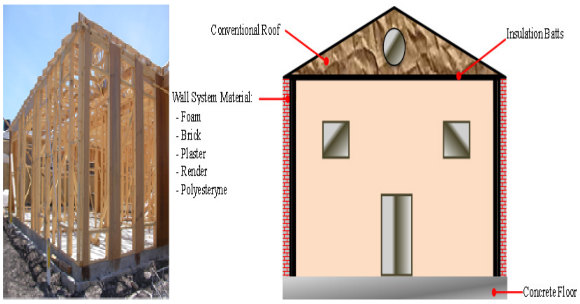


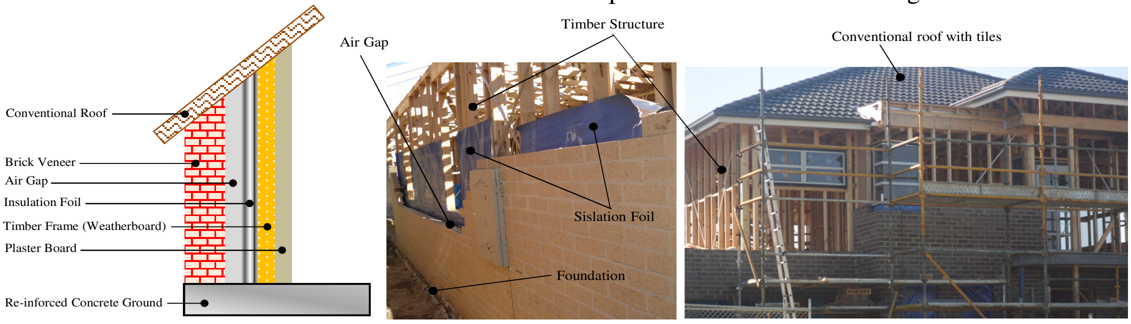
Fig. 4: A typical residential house design and material used

3.2 Construction system of conventional wall Design

The internal wall is generally made of approximately 90 mm timber stud structure and 10 mm plasterboard from both sides. The roof structure is made of timber with terracotta/concrete tiles and/or corrugated iron sheet [2]. The conventional external wall system generally consists of 110 mm brick veneer, 50 mm air gap, thin sisalation foil, approximately 90 mm timber stud structure filled with insulation bats, and 10 mm plaster board from inside. Figure 5a shows the exterior of a conventional brick veneer wall construction system of a typical residential house. Figure 5b illustrates an example of the brick veneer house under construction in outer Melbourne metropolitan city.

3.3 The proposal design for new wall system (exterior insulated material)

The new wall construction systems is made of 150mm exterior reinforced concrete and exterior insulated material, 50 mm polystyrene or fiber panels, and/or compressed straw and 10 mm render. From inside install 10 mm plaster board. However, the roof structure is kept as conventional without any changes. It is expected that the thermal performance of proposed construction material would be better than the conventional wall structure. Nevertheless, the conventional wall construction system has major disadvantages in that it needs more energy for ongoing heating and cooling to maintain a comfortable living inside the houses during different phases of exterior temperature change in varied climatic zones. Schematic of a new wall arrangement system and a typical reinforced concrete panel house are shown in Figure 6.



a) Schematic of Conventional House Wall

b) Conventional house Wall Systems with Roof under Construction near Melbourne, Australia

Fig. 5: Common house construction system in Australia (Aldawi et al. [16])

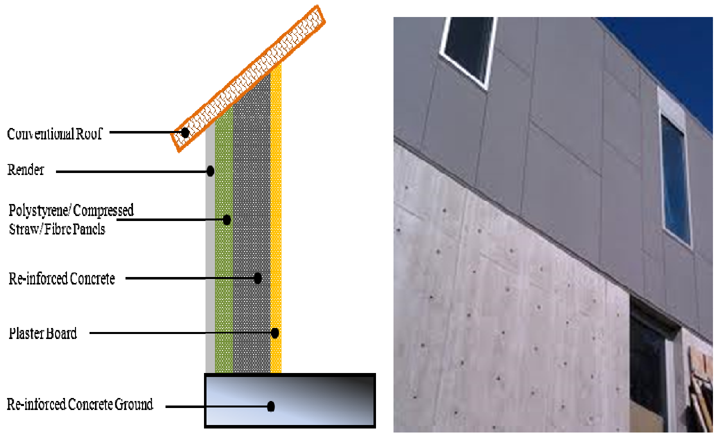


Fig. 6: New house wall with re-in forced concrete panel

4. RESULTS

The two residential houses wall systems (conventional and smart wall system) have been simulated in AccuRate software for two climatic zones. The results obtained show the thermal performances of two house wall systems located at two completely different climatic zones. As mentioned earlier the two locations are Melbourne and Alice Springs. Wall materials and their thicknesses were the input parameters for both houses which were fed into the 'AccuRate' software. The roof structure, window configurations, foundations doors, internal walls – were all kept constant. In addition, the type of windows, doors, floors, ceiling, roof, local latitude, shading schemes and direction of openings (windows, doors) of the house with respect to the flow direction of air were entered into the AccuRate program. Figure 7 indicates star energy rating for required heating and cooling energy for various regions (cities) in Australia. Based on varied climatic conditions, metrological data, and the solar radiation, the entire of Australia has been subdivided into 69 climatic zones with a certain amount of energy required for heating and cooling. This energy requirement rated against a scale from 0 to 10. These scale ratings are called Star Energy Ratings. The star energy rating includes energy requirements for ongoing heating and cooling only. Figure 8 shows seven main climatic zones of Australia. Each of the 7 main climatic zones has also been sub classified into multi zones. All of these multi zones make a total of 69 micro climatic zones across Australia [15].

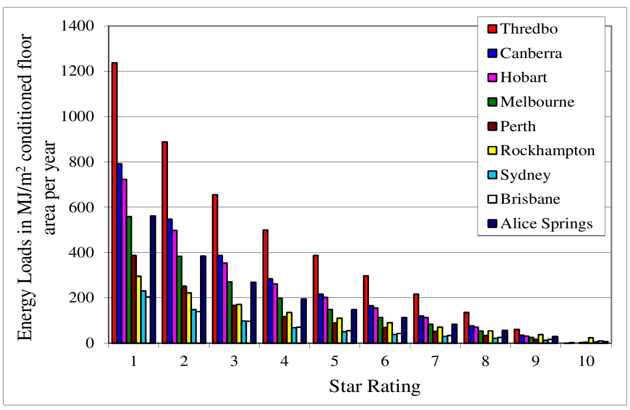


Fig. 7 : Standard energy loads against star rating for various cities across Australia [16]

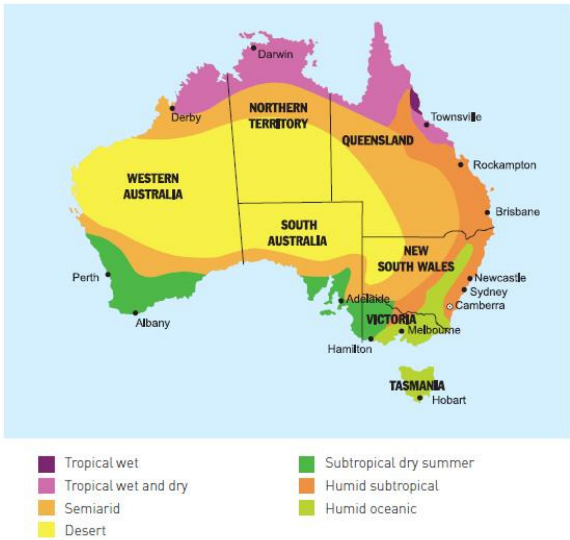


Fig. 8: Different climatic zones in Australia [15]

4.1 Thermal performance of conventional wall systems in Melbourne and Alice Springs

Since mid 2008, according to state and territory governments regulations, all new houses must comply with a minimum energy star rating of 6 for ongoing heating and cooling, especially in Melbourne and most parts of South Eastern Australia. The 6 stars energy rating means the house should not require more than 114 MJ/m^2 per year for Melbourne and 113 MJ/m^2 per year for Alice Spring. Using the AccuRate software, the conventional house wall configuration requires 124 MJ/m^2 per year for ongoing heating and cooling. It means the energy performance be rated only at 5.7 stars in Melbourne. On the other hand, the conventional wall configuration in Alice Springs requires 142 MJ/m^2 per year for ongoing heating and cooling and energy performance be rated only at 5.2 stars.

4.2 Thermal performance of new wall systems in Melbourne and Alice Springs

The total energy required for heating and cooling for the house with new wall systems in Melbourne is around 105.1 MJ/m^2 per year which equals a 6.3 star energy rating. A reduction of 17.9% compared to the conventional house wall systems. However, in Alice Springs, the total energy required for heating and cooling is 61.1 MJ/m^2 per year which is rated at 7.8 stars. Tables1 and 2 illustrate these results.

Table 1: Melbourne City

	Heating Load (MJ/m^2.annum)	Cooling Load (MJ/m^2.annum)	Total Energy Required (MJ/m^2.annum)	Star Rating	Star Symbol
Conventional House Wall	100.1	24.6	124.7	5.7	★★★★★☆
Alternative Wall System	96.5	8.6	105.1	6.3	★★★★★★

Table 2: Alice Springs City

	Heating Load (MJ/m^2.annum)	Cooling Load (MJ/m^2.annum)	Total Energy Required (MJ/m^2.annum)	Star Rating	Star Symbol
Conventional House Wall	3.9	138.1	142	5.2	★★★★★
Alternative Wall System	14.2	46.9	61.1	7.8	★★★★★★★☆

5. DISCUSSION

Depending on various climatic zones, a small modification in the wall structure and material can have drastic effects on residential ongoing energy performance throughout the year regardless the ambient temperature variation during day and night. As shown in Melbourne, the proposed house wall construction system has significant energy savings up to 15% whereas 50% improved in Alice Springs. This energy saving will reduce significant greenhouse gas emission and enhance the energy security.

A total life cycle assessment of the new construction system is also required for the full utilisation of the system. Further study is required for the cost analysis of the proposed wall system for the economic viability and wider acceptance as an alternative construction systems, methods and materials.

6. CONCLUSION

With the current building materials and construction methods, the conventional houses in Australia are not energy efficient and increase the threat of global warming; it is extremely difficult to achieve energy savings for ongoing heating and cooling. Additionally, the current construction method needs longer construction time and skilled manpower. As a result, the house construction cost is going up. Most conventional residential houses have lack of sufficient thermal mass, insulation and sustainability of design. This results in inefficient use of heating and cooling systems in the house under varied ambient conditions. The proposed wall system has better thermal performance and insulation characteristics compared to current house wall systems. The new house wall system may allow the exterior wall to have the higher thermal mass. The higher thermal mass helps to keep the inside of the house cooler during the day in summer due to its large heat carrying capacity. Similarly, in winter the material with higher thermal mass will help keep the inside of the house warm during the night.

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