SUSTAINABLE RESIDENTIAL LOW DENSITY URBAN DEVELOPMENT – INTEGRATING SUSTAINABLE CONSCIOUSNESS WITH COMMERCIAL VIABILITY

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Summary

This paper will discuss the present integration of sustainable features in a self-contained residential development in the growing urban density in Malaysia - consisting of 36 units semi-detached and 4 units terrace houses – within the constraints of commercial viability of such a project. The projects features the layout planning for green-shared landscaped courtyard area, a rainwater harvesting system links all units for landscaping needs, double brick walls for energy efficiency, heat reclaim system for hot water and roof insulation for heat gain reduction. Each unit features a four-storey structure with a double frontage design, foyer space in the 1st level. Dining, kitchen and living on the 2nd level. Bedrooms and a family room on the 3rd and 4th level. The focus includes the outcome of an evaluation of the energy efficiency impact of the double cavity external wall and a heat reclaim system used in each unit in the development - where air conditioning heat is reclaimed at night for hot water use in the morning. A solar shadowing impact of two adjacent developments consisting of high-rise condominiums on the entire developments for different times of the day were also done to ascertain roof surfaces which can be used for grid connected solar panels. The paper presents an attempt by an ecological conscious developer to integrate green features – including rainwater harvesting and communal strategies such as shared green space within the commercial and resource constraints of a project.

1. Introduction

The paper presents a recent housing development in which the developer attempted to integrate a range of sustainable features, within the costs constraints of the project. It represents an initial model for upper middle class housing – a section of society, which typically consumed high energy within their lifestyle. This residential development consisting of 36 units of semi-detached and 4 units terrace houses in a gated community. Each unit's built-up area ranges from 3719 sq.ft. to 4333 sq.ft. The units are aligned in a courtyard arrangement with a central communal garden with communal facilities such as gym and multi-purpose hall located at opposite ends of the courtyard. Of particular interest is the impact of the use of double cavity brick as external wall material in the first three levels of the house – particularly in terms of reducing the heat gain into the internal space. The impact in terms of reduction in energy use and improved occupant comfort are also of interest. Ecological features implemented in the development but not tested in this study include a rain harvesting system, which collects rainwater for landscape maintenance in the development.

Due to the rapid rise of urbanization and development in urban areas in Malaysia, a rise of air-conditioning use has also been observed. This is related also to the widespread availability of technology and the rising income and lifestyle of city dwellers. The assumption of air conditioning usage reverses the prioritization of bioclimatic strategies from open-planning/lightweight construction towards more heavyweights, thermal mass, compact massing and planning. The following is a summary of a study of the impact of selected features in a residential development consisting of 36 units of semi-detached and 4 units terrace houses in a gated community.

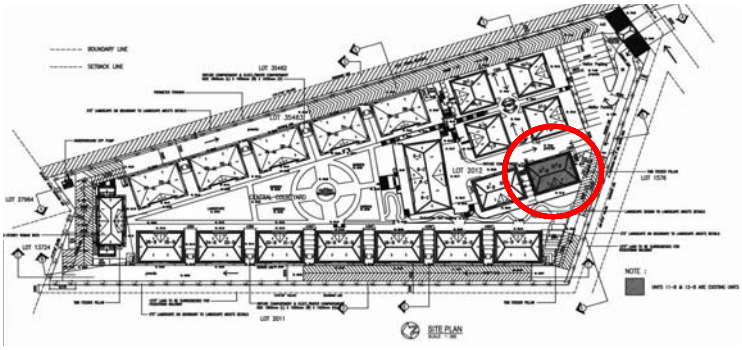

Figure 1 *Site Plan - Whole development highlighting the location of unit modeled in study*

1.1 Orientation of model (whole development)

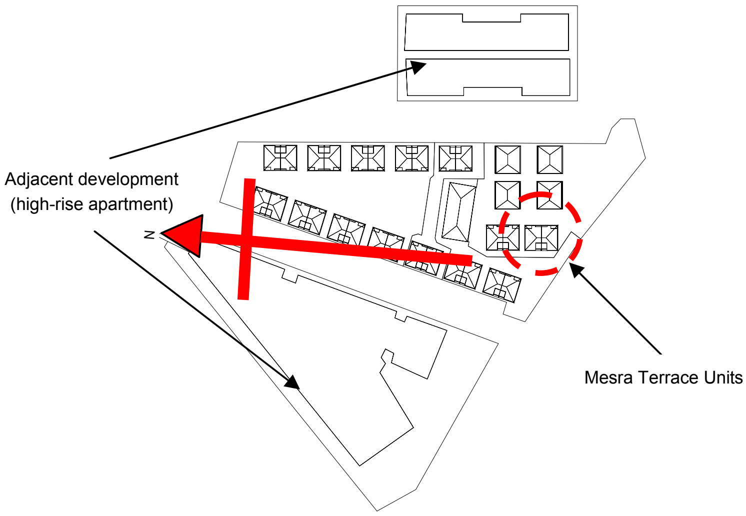

Figure 2 *Orientation of model – Whole Development including all units and adjacent high-rise apartments (selected unit for study highlighted)*

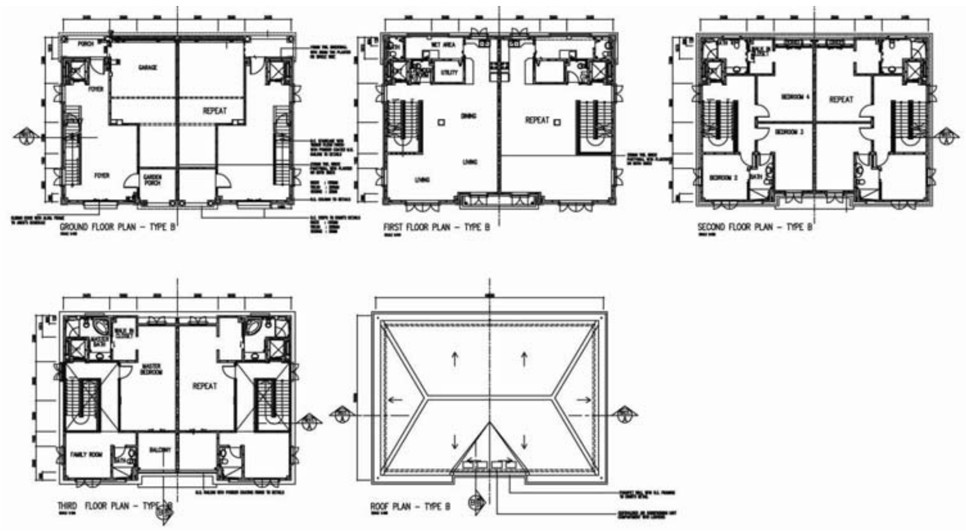

Figure 3 *Typical floor plans (All floors - Selected unit – BEDFORD)*

1.2 Layout and Planning

The layout of the development is aimed at a communal way of living, where units are arranged around a central courtyard that acts as communal space. In this way, green open spaces are utilised in an optimum manner, and maximised for the benefit of the community.

Figure 4 Overall layout and planning of the Mesra Terrace Development

1.3 Simulation Studies – Multi-Zonal Analysis

The MULTI-ZONAL ANALYSIS tool is used to analyze the impact of infiltration and natural ventilation in the building on the predicted temperatures within the internal spaces which are linked an assessment of the thermal comfort conditions of occupants. Under Malaysian conditions, comfort conditions for users and occupants can be enhanced through both mechanical means and enhancement of certain passive design features. Basically under the Malaysian conditions, comfort is difficult to achieve - particular in the daytime - but can be primarily enhanced through inducing cross ventilation and air movement and reducing solar gain and heat gain from all potential sources. The analysis uses a zonal-airflow model to calculate bulk air movement in and through the building, driven by wind and buoyancy induced pressures.

1.3.1 Internal Temperatures

The internal temperatures were analyzed using a multi-zonal tool. The following figures show the internal temperature patterns for one week in January for selected spaces in the house. The results also show trends for one representative day in January. The internal temperatures are compared with the external temperatures taken from the external weather data used in the program. The focus of the output is:

- The foyer, family and living, and selected bedrooms
- With and without cavity brick wall for selected areas

1.4 Assumptions (all models)

1.4.1 'All windows closed'

In almost all models and options, the windows are assumed to be closed. The aim here - and justification - is to attempt to highlight the impact of the double wall option on the internal temperatures. This serves to isolate the impact of heat gain through conduction gains through the external wall. Hence ventilation gains are not included in this calculation (except for infiltration gains - which is set at 0.5. ac/hr).

1.4.2 'With selected windows opened'

In the multi-zonal analysis, only the categories 'External glazing', 'Internal glazing' and 'Door' are important. Elements in these categories are called 'openings'. They may be assigned data allowing the tool to simulate the passage of air through them. An opening type is a type of building element which can be selected and consists of a specification of the element's air flow characteristics and the way they vary with time.

In the energy analysis, it is assumed that only the windows in one bedroom are opened for a total of two hours to 'air' the house.

In terms of internal temperatures, under naturally ventilated conditions i.e. the more windows are opened, the more the internal conditions will follow closely the external climatic conditions. Under such naturally ventilated conditions, improved comfort conditions depend on higher indoor air speeds. The flow of outdoor air through a building extends the upper limit of the comfort zone beyond the limit for still air conditions and this provide a direct physiological cooling effect. Hence when efficient cross ventilation is achieved during daytime, the temperature of indoor air and surfaces closely follow that of the ambient air temperature.

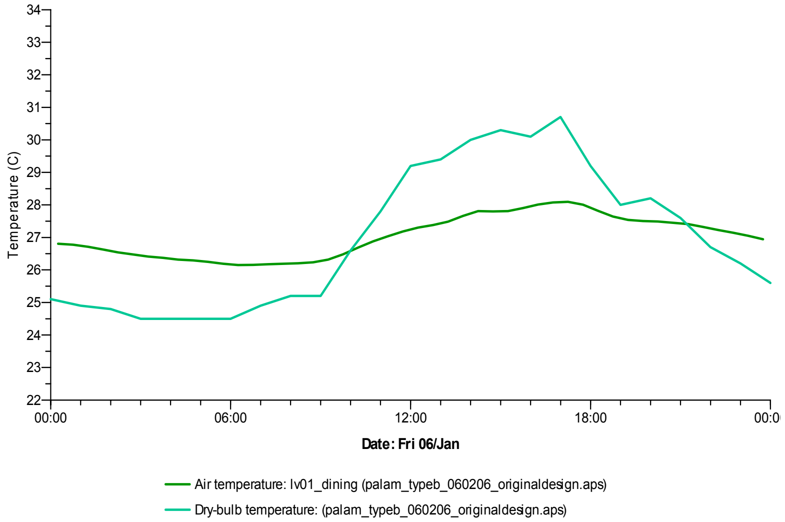

Figure 5 *Temperature distribution in dining area for one representative day in January (internal vs. external temperature) with cavity wall (windows closed, A/C OFF)*

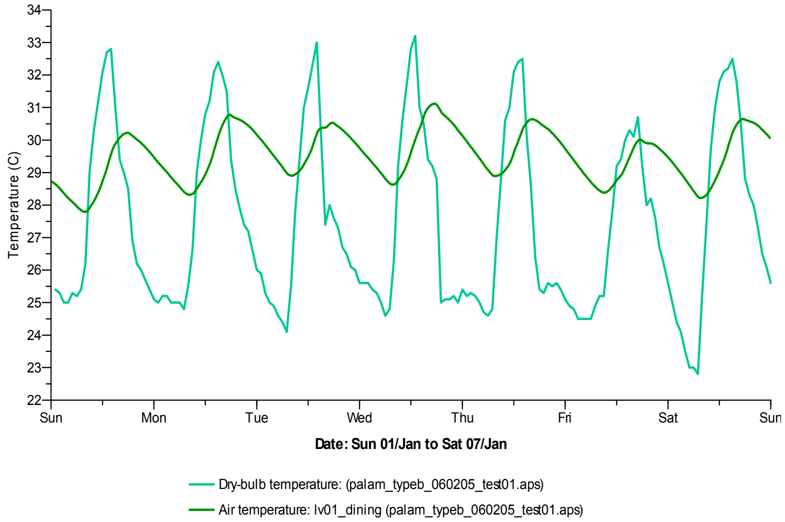

Figure 6 *Temperature distribution in dining area for one week in January (internal vs. external temperature) without cavity wall (windows closed, A/C OFF)*

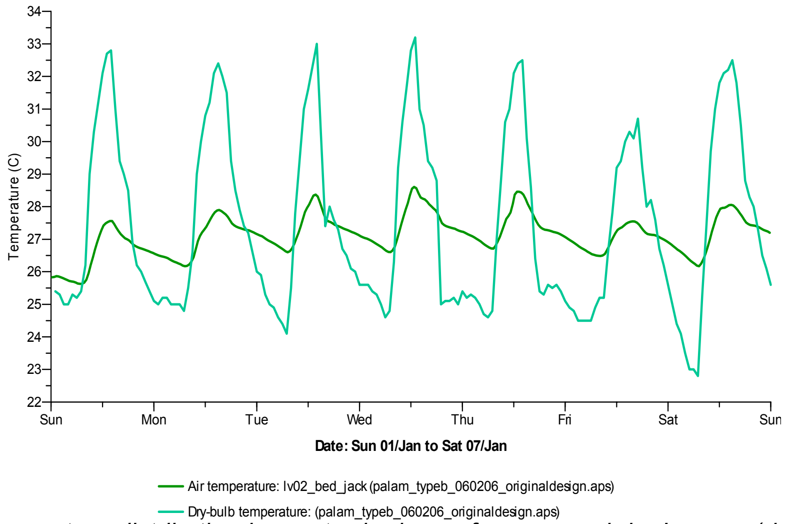

Figure 7 *Temperature distribution in master bedroom for one week in January (internal vs. external temperature) with cavity wall (windows closed, A/C OFF)*

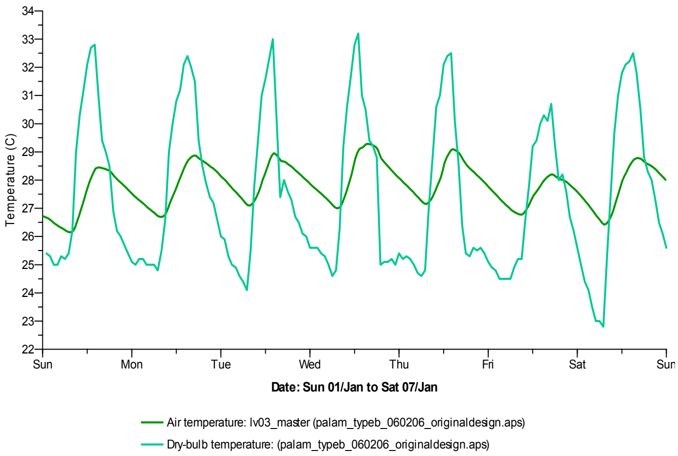

Figure 8 *Temperature distribution in master bedroom for one week in January (internal vs. external temperature) without cavity wall (windows closed, A/C OFF)*

2. Energy Saving Estimation of the Condenser Heat Reclaim System

An energy saving feature of the development is the heat reclaim system installed in selected rooms in all units. Typically there is an amount of energy required for the heating of the water - this is linked to all the bathrooms within the house. This heating requirement if supplied by conventional electrical heaters, the total cost of energy use per year would be considerable. Heat rejected from the air conditioning condensers represent energy that can be reclaimed at the supply water tank to save a considerable amount of the total cost of water heating.

2.1. Estimation and parameters in calculation

Assuming that the heat reclaimed from two cooling units of full capacity (2.93 kW operating according to the schedule), the coefficient of performance of the air-conditioning system (COP) is taken as 2.0 and the cooling set temperature is taken as 24°C.

Using the annual weather conditions data for Subang Jaya (1995), and according the operation schedule as shown above, the total electrical energy can be estimated for the cooling of the two of the bed rooms in the unit. This calculation takes into consideration the climatic variation throughout the year. The combined mechanical and electrical efficiency of the compressor can be considered in the range of 65%, and the heat exchanger efficiency at the water storage tank is taken as 80%. The following equations are used in this calculation;

$$COP = \frac{Q_L}{W} \quad (1)$$

$$Q_H = Q_L + W \quad (2)$$

Where COP is the coefficient of performance of the refrigerator, Q_L is the cooling load, Q_H is the heat rejected at the condenser and W is the compressor work. Table (1) shows the values of Q_L and the reclaimed heat for the whole year.

Table 1 *The values of Q_L and the reclaimed heat for a whole representative year.*

Date	Q_L(MWh)	Q_H(MWh)	$Q_{Reclaimed}$(MWh)
Jan 01-31	1.3	1.2	1.0
Feb 01-28	1.2	1.2	1.0
Mar 01-31	1.5	1.5	1.2
Apr 01-30	1.5	1.5	1.2
May 01-31	1.7	1.6	1.3
Jun 01-30	1.6	1.6	1.3
Jul 01-31	1.7	1.6	1.3
Aug 01-31	1.4	1.4	1.1
Sep 01-30	1.5	1.4	1.2
Oct 01-31	1.5	1.5	1.2
Nov 01-30	1.3	1.2	1.0
Dec 01-31	1.2	1.1	1.0
Summed total	**17.3**	**16.9**	**13.5**

From the results presented Table 1, it can be concluded that **a total of 13.5 MWh of heating energy can be saved which means a total reduction in the water heating cost of about RM 3800 per year**.

3. Rain Water Harvesting

The development is designed with a Rain Water Harvesting system to capture runoff from the roof. The system is designed to collect water that is captured at gutters into downpipes and store it into an underground tank placed at the center of the courtyard to for landscape maintenance purposes. As Malaysia receives an average of 1000mm of precipitation annually, the development capitalizes on this advantage to retain some amount rather than to let all the free water runoff to the public sewer.

The system focuses on reorienting the plumbing design so that water from gutters can be brought down using uPVC pipes directed it to a 2ft-deep sump. The water then goes into a filtration system to filter out debris and to make sure the stored water is clear of sediments. These waters will then be stored in a large tank underneath the central pond at the courtyard centre, and can be used by using a motorized pump to push the water back up and water the lush landscape.

The design also takes into advantage the natural slope condition of the site, placing the 4 x 20 x 1.5m rectangular tank in the dead centre on the site before re-distribution. The tank is connected by 5 main lines of water catch pipes from 2 main 150mm Ø uPVC feeding pipe lines.

With proper technology, these waters can also be used for day-to-day needs like drinking and cooking purposes. If the maximum collection is 90% efficient, the net amount of rainwater harvested annually amounts to approximately 1,200,000 litres that would benefit in saving water thus reducing water bills.

LEGEND					
	Water outlet for utility usage		65Ø HDPE recycle water supply pipe		150Ø uPVC recycle water collection pipe

Figure 9 Water-harvesting system diagram

Figure 10 from left – construction detail showing water harvest system at the community center & Rain water downpipe and the collection sump under construction

4. Roof ventilation design and insulation

To reduce internal temperature in areas below the roof, the roof was designed with heavy insulation. The roof design is a 20mm thick concrete roof tiles with light grey color finish. The use of light color was chosen to help repel heat. The roof tiles are made to rest on timber truss rather than a galvanized iron (G.I) truss. G.I. is commonly practiced in the Malaysian construction industry due to its low cost. The use of timber truss is because timber has a lower emissivity value which emits lower heat radiation. The insulation material used is a woven insulation foil, backed by fiber quilts and secured by a wire mesh to the soffit of the roof truss. As commonly practiced, these layers are then covered by a plastic sheet to make sure the fibres or dust will not fall and gets into the interior space. Not only that the layers repel heat, it also repels noise.

Figure 11 Roof construction layers

4.1 Roof ventilation system

To help trapped air escape from the roof area, the ridge is installed with ventilation holes using a ventilation product. The product is rubber based and is flexible. It is placed under the top most tiles before the ridge. As it is placed at the top, hot air raises and escapes through the deigned outlet. Figure 12 is showing the test session on the product. The system was testing for smoke escape as well as rain penetration at high horizontal winds. These studies were also crucial for fire departments approval for the building design's low party wall. The study shows a majority of smoke flow out from the roof area through these vent holes suggesting the performance of the product which makes the roof area to "breathe" which increases thermal comfort.

Figure 12 Roof construction mock up: to test the ventilation device effectiveness.

5. Discussions

Overall, the results demonstrate the thermal benefits of increasing thermal mass i.e. use of a more massive structure (such as a double cavity wall) - which amongst others, are the attenuation of the daily temperature swings and slight delay in reaching peak temperatures during the day. The difference in peak temperatures may range from 3°C to even 6°C during the day. The day night variation is also reduced from a range of 23-33°C to 26°C to 28°C. In this study, the indoor peak temperatures are found to occur at about the same time as the outdoor peak temperatures. The results thus demonstrate that the double wall has a positive impact on considerably decreasing surface temperatures and consequently, internal temperatures within the house.

The results reflect the general principle that the use of increased thermal mass in a building reduces and attenuates peak temperatures during the day. However because it stores some of the heat, it later releases some of these heat during the night –partially to the outside and partially to the inside of the building.

In colder climates with large diurnal swings, the re-radiated hear may be beneficial to offset heating requirements, however under the hot, humid climate, the increase in nighttime temperatures may lessen the impact in terms of energy savings – particularly when the A/C is used predominantly at night. Hence in such a case the use of ventilative cooling (cooling effect through air movement and ventilation) can be an effective strategy when employed at night.

The significant effect of the double wall can be particularly felt in space facing the full impact of the afternoon sun such as the master bedroom which shows a marked decrease in peak temperatures in the afternoon. (Refer *Figure 6 and 7*)

Similar results has been found in studies by Szokolay (1990) for example, which showed that in the tropical humid climate (in the case of Queensland), most comfortable conditions all year round was achieved by a 'heavy' construction (in this case slab-on-ground floor, reverse brick walls with insulation on the outside of the mass layer, a well-insulated roof and full shading of all windows) through the application of heavy construction. Cooling through passive means such as ventilation should be encouraged at night.

This has been supported by other studies such as Machado (1999) who tested a house design for the climate of Venezuela. The study found that the best performance was achieved by a heavy weight building with night ventilation. Soebarto (1999) also found that for the climate of Jakarta (Indonesia) for a heavyweight house, daytime closure of the windows kept the inside 3-4 deg K cooler than the outside. Hence in purely temperature terms, a building (with closed operation during the day) is slightly better as the heavier mass would also reduce the peak load and hence reduce energy use.

Conclusions

The project is an important attempt to incorporate a range of sustainable features which are in line with international rating systems and in line with the general definition of sustainability. In developing countries such as Malaysia, due to the drive for progress, sustainability is not a cultural-ideological movement - compared to the more developed countries. Many of the features in this project were initiated by the developer, while designers, researchers and suppliers provided the technical input in terms of design, specification, simulation and calculations. The developer is working within the constraints of not only, lack of institutional support within this context for sustainability, but also the press of fulfilling commercial and financial viability of the project. Though this project represents an urban gated community development targeted for the upper middle class homeowners, it can be argued that sustainability should be targeted to this group of people since they have the means of both ' spend' and 'save'. They are also a strata within society who are open to new forms of living, and whose level of education and lifestyle have given them exposure to sustainable ideas and ways of living. This is an important project which highlights that sustainability can be practised within the time constraints and financial limits of a commercial project.

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