INVESTIGATIONS AND RECOMMENDATIONS FOR TOWNHOUSES IN BANGKOK THROUGH SIMULATIONS OF THERMAL PERFORMANCE

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ABSTRACT

In view of contemporary building practices in the tropics whereby climatic factors are 'sometimes' neglected, this research paper puts forward some investigations and recommendations on what is appropriate for tropical buildings in the residential sector: Townhouses in Bangkok. One of the obvious failures of modern architecture in the tropics is the failure to accommodate the impact of climate. A good example of this failure is especially seen in the use of inappropriate materials and the excessive decoration of the building envelope without consideration of its heat accumulation and therefore its impact on the comfort levels of living space and energy consumption. In view of the foregoing the paper investigates townhouses in the area of Bangkok through simulations on thermal performance with the aim to generate results which will contribute to educational and professional practice.

1. INTRODUCTION

In locations close to the equator ambient temperatures and solar radiation levels are high and in general outdoor temperatures (T.amb) are higher than the required comfort levels of indoor living areas. The envelope of the building protects the inhabitants from the sun and has to guarantee for certain times sufficient comfort levels without any or little help of mechanical cooling systems. Particularly during day times the envelope should provide sufficient protection to avoid overheating at night.

The maintenance of indoor comfort levels in present buildings is usually ensured by air conditioners. However a reduction of interior temperature by means of a suitable design can reduce the cooling load of the air conditioner and decreases the electric consumption of the building significantly. On the other hand appropriate materials protect and keep the cooled air inside the building. The heat gain of existing buildings consists of direct solar radiation conducted through building materials and entering through openings like windows (Suehrcke H., Peterson E., Selby N.). For the research, the aim is to simulate the temperature inside the townhouse (base case) and to reduce the heat gain by employing passive cooling strategies (layout zoning, tropical design elements) and suitable materials with high thermal resistance properties and low thermal capacity. Two cases are significant for the paper, the corner units of a townhouse row (6 units) with four elevation (side, front, back and roof) and the center unit with three elevations (front, back and roof). Various comparisons are simulated: The base case, re-design and re-design with night cooling.

2. METHODOLOGY

For the research a building energy simulation tool, BESim (Building Energy Simulation program), was used. Based on existing typical townhouse planning a model with parameters and dimensions of materials was constructed where the software calculated indoor temperatures based on recorded climate conditions. Average temperature data was used from the *Thai Meteorological Department*.

The results of the simulations are based on various steps which include the analysis of first, the Base Case, the evaluation of its simulation results, and second based on it the development of a strategy to improve assessed problems in thermal heat gain. The strategy was applied and the design alternated and simulated again to verify the strategy and argumentation. In case of no improvement the applied steps of improvement were revised and simulated again. The indoor temperatures of both models/results (base case and redesign) were compared with each other and new steps undertaken to improve further.

The simulations did not take into account reflectance characteristics of the roof. No human, lighting and equipment load were considered. All windows were closed. To avoid any interference from other external factors that could have an impact on the results, such as site typology, density of surrounding buildings and vegetation, were excluded from the simulation. The aim is to show the best possible results without any influence of the user and context with the consideration of heat gain from the outside only.

The simulation results are in graphical and tabular format: The temperature is shown in a diagram where the temperature of each room is put in relation to day and night time for a particular month, April: The hottest month in the year according to the recorded data.

The specifications for the materials are according to the existing planning. Changes were considered in regard of the thermal physical properties of the materials, the overall coefficient of heat transfer, the U-value and the thermal mass capacity (J/m2K).

2.1 Base Case - Typical Townhouse

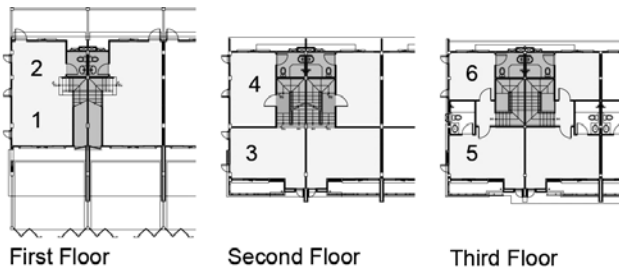

Figure 1: Floor plans (Base Case)

The base case for a typical townhouse planning (*Figure 1*) is according to existing development of real estate housing in Bangkok such as SANSIRI and PRUKSA. A basic unit is 5.5m wide and 9.7m long with a total living area of 195m2; 6 units create a row of 40m width, restricted to the building code. Each unit comprise of a (1+2) living and dining area, (3) family room open to the ground floor, (4) bedroom 3, (5) bedroom 1 and (6) bedroom 2. In each floor a WC and bathroom respectively faces the back side of the townhouse with a small window. All floors are connected through an open staircase (red color) on the inside wall from which all rooms are accessible. On the East and West side, the corner units have additionally windows.

Building materials (*Table 1*) are according to the existing planning: In general the main structure is formed by concrete columns filled with brick stones. The roof is covered by concrete tiles without any additional insulation. Windows are generally single glass, green tinted to filter and absorb infrared radiation.

Table 1: Building Materials - Base Case

	Materials	U-value (W/m2K)
Roof	Concrete tile	-
Ceiling	Gypsum board, 10mm	R = 0.0524 m2K/W
Wall	Brick with plaster, 10cm 20 cm	3.322 1.942
Window/ Sliding door	Green glass, 6 mm	5.25
all floor finishing's	Concrete slab and Ceramic tile	-

2.2 Revised planning

The revised planning *(Figure 2 and 3)* follows passive cooling strategies for tropical architecture and consists of proper zoning to create thermal buffer zones on the East and West side by utilizing the stair case and bathrooms (Lerchner N.). On the other side, the interior walls, are aimed to have high thermal capacity to store the cooling load of the A/C and with its slower response time to radiate back during the day time. Exterior wall materials were considered for their heat transfer capacities to prevent the heat transfer and to reduce the heat accumulation (*Table 2*). In comparison to the Base Case, the roof is upgraded with Fiberglass insulation; window properties remain the same, but additional sun shading devices are employed and a roof skylight for ventilation is employed.

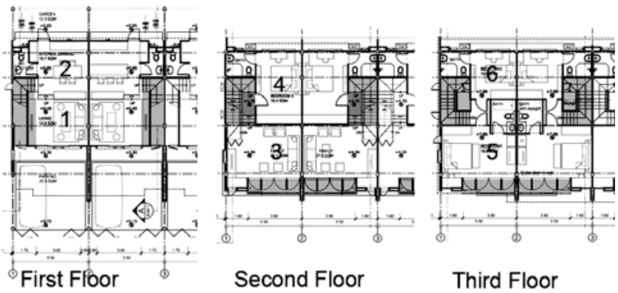

Figure 2: Floor Plans (Revised planning)

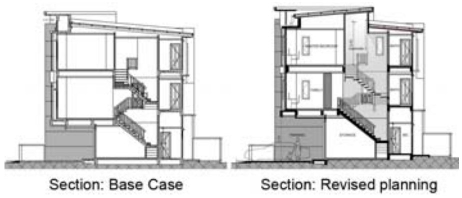

Figure 3: Sections - Base Case and Revised Planning

Table 2: Building Materials - Revised planning

	Materials	U-value (W/m2K)
Roof	Concrete tile, Fiberglass, 50mm	R=1.515 m2K/W
Ceiling	Gypsum board, 10mm	R = 0.0524 m2K/W
Wall	Exterior wall: Cement plaster 1.5cm, Cool block 7cm, Cement plaster 1.5cm	0.6755
	Interior wall: Brick with plaster 10cm 20cm	3.322 1.942
Window/ Sliding door	Green glass, 6 mm	5.25
All floor finishing	Concrete slab and Ceramic tile	-

2.3 Revised planning with night ventilation

According to the data the outdoor temperature (T.amb) ranges from about 39ºC during daytime, to 26.5ºC at nighttime at its lowest point. Ventilation of the townhouse takes place at 12am with T.amb = 27ºC.

3. SIMULATION RESULTS

3.1 Corner Unit facing East/West side

The Base Case (*Figure 4*) shows high temperatures during the day on the 3rd floor in bedroom 1 and 2 which are up to 5ºC higher than T.amb (outdoor Temperature). The difference remains constant until late night. Other rooms are in generally cooler than T.amb until 4pm where the sun is on the West side and can heat up the interior space, although in the morning until 8am, T.amb seems to be higher than the interior Temp. The revised planning (*Figure 5*) shows an improvement, especially of bedroom 1 and 2 which now have lower temperatures, where as the temperature in the other rooms increases slightly; the temperature curve becomes more even throughout the day and is due to the improved properties of the materials where the occurred heat from the windows remains in the house and can't escape. *Figure 6* shows a great improvement through the release of the trapped heat at night time. The temperatures are equalized at night and in average lower than the base case. The occurring heat in the townhouse does not exceed T.amb in the daytime, only at 4pm in bedroom 1 and 2 on the third floor due to the insufficient shading devices on the West side.

3.2 Center Unit facing North/South side

In comparison to the corner units, the center units have no side elevations and are protected from the West and East side. The sun radiation has an impact on the South, North elevation and the roof. The Base Case (*Figure 7*) shows high temperatures in Bedroom 1 and 2 on the third floor during the day, due to the lack of insulation in the roof layer. Other rooms, on the 1st and 2nd floor have significantly high temperatures; especially at night time the indoor temperature is 3-4ºC higher than the T.amb, whereas during the daytime the effect is reversed and the indoor temperature is 4 ºC lower. This is due to insufficient shading devices which allow partially direct solar radiation through the windows with its high U-value and the front and back facade with high thermal mass that reflects back the absorbed heat overnight.

The revised planning *(Figure 8)* shows significant improvement where the overall temperature decreases up to 4ºC. Bedroom 1 and 2 are almost even with T.amb during the day, however at night the temperature is higher than outdoor. The other rooms have a slight improvement, although are similar to the base case. Nevertheless the temperature curve of all rooms inside the townhouse becomes even. Less differences occur between the floors.

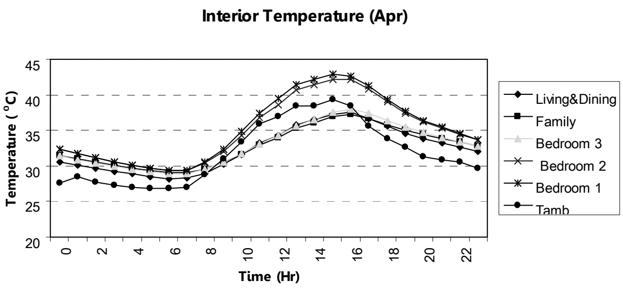

Figure 4: Base Case

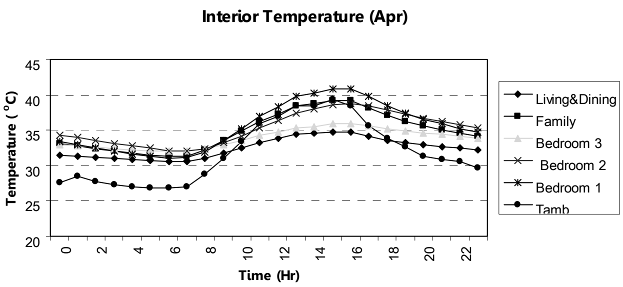

Figure 5: Revised planning

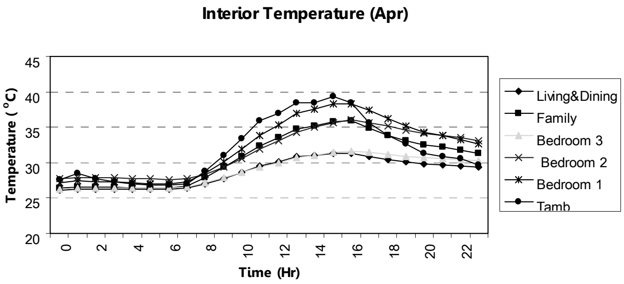

Figure 6: Revised planning with night ventilation

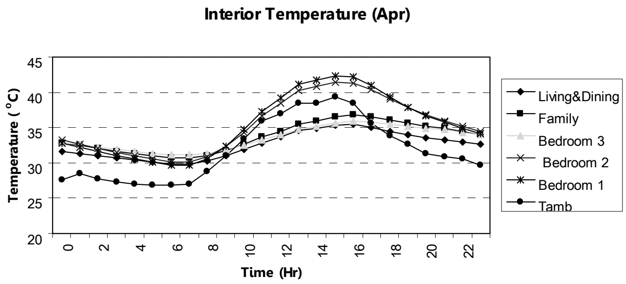

Figure 7: Base Case

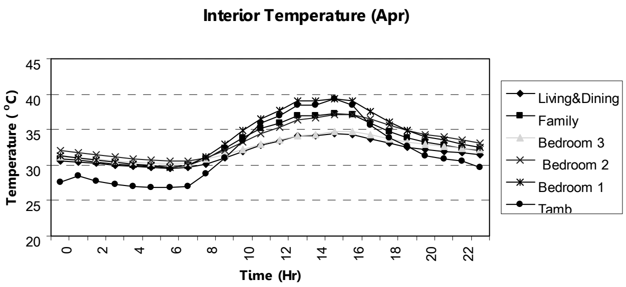

Figure 8: Revised planning

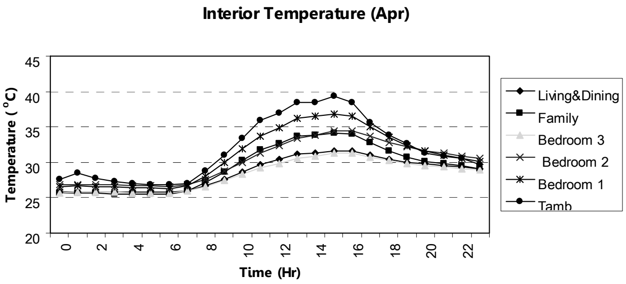

Figure 9: Revised planning with night ventilation

The new employed materials with low thermal mass and low U-values protect and do not absorb heat to radiate back into the interior space, however heat is transferred through the windows and is trapped inside.

Figure 9, revised planning with night ventilation improves the temperature situation; the improvement is clearly visible once the hot air is released at night. The temperature is either equal with T.amb or is lower during the day. Remarkably the indoor temperature never exceeds the outdoor temperature which is due to the lack of the East and West elevation where heat can enter the townhouse through the windows. All rooms show lower indoor temperatures in comparison to the other cases. Differences between front and back rooms and each floor are visible and can be lead back to the size of the openings where the heat is transferred through the windows with high U-values.

CONCLUSION

The results are a chain of reasoning due to taken measures, such as zoning (buffer zones) and employment of materials with higher thermal resistance for the building envelope. According to the simulation, materials with small thermal capacity are recommended particularly for the exterior walls where the direct sunlight is unavoidable. For the interior walls materials with higher thermal capacity are desirable to accumulate the coolness provided by either mechanical cooling systems or by night time cooling through ventilation. The biggest impact on thermal performance has the roof where insulation is mandatory. On the other side additional protection of the exterior walls with insulation showed less impact on the calculations, but lower thermal capacity guarantees better comfort levels and the interior can be easily cooled down without any loss of additional cooling energy.

During the day windows are closed to protect the interior space from hot outdoor air. Where necessary, openings need sufficient shading devices to protect the interior space from direct sun radiation especially the East and West side. However it is not always possible to protect the facade utterly, due to restrictions of the design (appearance) and selling points (view and openness.) In this case windows with lower U-values and better quality in terms of sealing are recommended to minimize the transfer of heat from the outside to the inside. Also better U-values improve the heat convection and minimize the entry of heat into the interior.

Ventilation at night is a very important factor for buildings with less thermal capacity and usually neglected. In case of insufficient ventilation the heat is trapped and heats up in the following days. Even the accumulation is low, but the air becomes hot. To reduce the cooling load it is necessary to ventilate during times where the outdoor temperature is lower than the interior.

Besides the improvement of material properties and the consideration of passive cooling strategies, other factors play an important role for thermal performance of a townhouse and therefore its energy consumption. Site planning, its micro climate conditions and the density of buildings in the environment have an impact on the indoor temperature: Reflectance, radiation and the lack of green areas increase the outdoor temperature. Green and less 'hardscape' areas are desirable, in order to benefit of lower temperatures.

However the most important factor is the human. In generally the planner is not considering the users behavior and on the other hand the user does not understand the energy system behind the planning, such as to close windows in the morning times and to avoid any exchange of cool with hot outdoor air. Mostly psychological reasons let the user open the windows. Therefore, even the best planning can only work efficiently if the user is informed and instructed by the planner how to use his/her townhouse.

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