Livable of the past-rural affordable settlement in current urban environment

F X T B Samodra* and I Irvansyah
Department of Architecture, Institut Teknologi Sepuluh Nopember, Kampus ITS, Sukolilo, Surabaya 60111, Indonesia

*fxteddybs@arch.its.ac.id

Abstract. In Indonesia, traditional houses were designed according to the rural environment, which had the maximum natural ventilation and minimum building heat gain. Currently, the occupant population and building growth are significant factors affecting energy efficiency. Moreover, technological advances demand electric applications, which results in higher internal heat gain and cooling loads, particularly in the lowland tropical regions, which has a higher temperature than upland areas. On the other hand, the change in an environment still controls the cooling loads with the minimum potency of wind speed to restore the thermal comfort as a new building adaptation model. This study aimed to evaluate the thermal condition and the energy performance of traditional tropical houses using the Ecotect Analysis program for cooling load analysis based on the field study data. The results showed that the highest cooling loads were the result of sol-air and internal heat gain elements. The building envelope's conduction factor significantly affects indoor temperature fluctuation indicated by a similar trend in heat gains and heat losses.

1. Introduction
The environment of traditional tropical houses is affected by the occupant population, and electric applications result in higher internal heat gain and cooling loads. The conditions are different from the original traditional houses, designed to result from the optimal model in rural environments and have the maximum natural ventilation and minimum building heat gain. Most of the occupants are mid-low income people, and they adapt to the ground by modifying the hot and humid living environment by creating higher air movement (turning on fans, opening the windows) [1,2]. These adaptive actions have become a part of their daily lives and indirectly dictate their thermal comfort expectations in natural ventilation buildings, intended as affordable housing. Specific adaptive actions, such as opening windows, are prevalent in all climate types, whereas particular activities, sitting on cold floors, are limited by the climatic and cultural traits [3].

At relatively high temperatures and humidity, adaptive actions do not appear very useful, and the comfort range is slightly smaller than that under more favorable conditions [4]. Taking solar energy into account when designing a new urban district can significantly contribute to renewable energy's local production [5]. Besides, solar zoning can contribute the solar access for solar energy in denser cities. Buildings can be designed to operate in a free-running mode to be comfortable when the prevailing mean outdoor temperature lies within the range, 10.0°C to 30.0°C [6]. Furthermore, the low-energy design of urban environments and buildings in densely populated areas requires considering a wide
range of factors, including urban settings, transport planning, energy system design, and architectural and engineering details [7]. The densification of towns can positively and negatively affect total energy demand on suitable green design for affordable housing [8]. With appropriate urban and building design details, the population should be accommodated with minimal adverse environmental quality effects. In addition to all the similar previous studies above, this study proposes evaluating the thermal condition and the energy performance of traditional tropical houses in current adaptation.

2. Methodology

The Javanese house's traditional tropical house was located in lowland Surabaya, one of Indonesia's most extensive and hottest cities. The building generally consists of 3 zones: The terrace, the main room, and an additional room (Figure 1). The main room is the most occupied zone, typically. The size of a traditional Javanese house is 6 x 7 m² with many variations in materials depending on the location and time factor. Recently, wood has been used for walls, and roofs are made from tile/clay as a building envelope. All materials used in traditional buildings are recognized as a lightweight material.

A field study was held at the end of July/early August, the coldest time, with little solar radiation intervention. The hottest month usually is October, which is also characterized by heavy rainfall and high relative humidity. In detail, the building performance in the hottest time will be explained by a simulation using Ecotect Analysis. The air temperature was measured using an air temperature data logger or recorder, 24 hours a day for one week, using the same tools but with different channels (Figure 1). Also, relative humidity measurements were taken to check the direct effects. All data loggers had a sensitive sensor's free condition with the maximum height location of individual activities (human standing = 1.5 m to 1.7 m). The anemometer was used manually for wind speed measurement in the critical time of activities (morning, afternoon, and evening) in a week.

![Figure 1. Building profile and measurement setting.](image)
3. Results and discussion

3.1. Past and today’s environment
As the model, Javanese houses, one of Indonesia’s traditional houses, have not been built since the early 20th century as a traditional building and around 1970 as local buildings [9]. This was attributed to social and economic problems, the colonization process, etc. Over the last 100 years, the temperature has increased by 0.002°C/year or 0.02°C/decade [10,11]. Although limited, the surviving buildings to be analyzed more to determine how they and occupants can adapt to be livable and make a comforting shift [12,13].

3.2. Field measurement and environmental simulation
The adaptive comfort behavior to the environment should refer to the contextual understanding. As additional discussion to the initial research [14], both measurement and simulation are directed to describe the potential and affordability of adapting the natural environment’s temperature and humidity. Although it is rare, the field outdoor and indoor air temperature and relative humidity measurements showed that the rain on the first day made a lower amplitude, similar to like the hottest month situation. Figure 2. shows that a higher amplitude affects the higher cooling or heating loads. Nevertheless, the increased solar radiation, in addition to the air temperature and relative humidity of the hottest month, still causes a problem in energy consumption, particularly for hot environments in lowland areas. At all times, the indoor relative humidity is higher than outdoors. This condition shows that the lower wind speed indoors compared to outdoors affects the ability to reduce the amount of water in the air relatively. There was no significant difference in the relative humidity, but the indoor air temperature was higher than the outdoor temperature. In addition to the minimum air movement problem, the high activities due to the occupant allow the accumulation of internal heat gain.

![Figure 2. Week field measurement in the coldest month.](image_url)

3.3. Thermal comfort analysis
For healthy living, this study proposes environmental comfort for affordable housing. In addition to the previous study [15,16], the findings are directed to improve thermal comfort to sustain the occupant’s living quality, and the mean radiant temperature (MRT) will represent the tropical thermal condition. MRT determined by the Equation at the sitting reference height was 30.0°C to 40.0°C. Solar radiation in a tropical climate makes a substantial contribution to the indoor air temperature. The main problem
experienced by the main room occurs in the left and right sides. It is influenced by the porous wall when sunlight penetrates the building and increases the temperature regardless of the air velocity. In standing reference height, the MRT has less performance than in sitting. The opening is located in standing reference height. The similar contour of MRT and a Predicted Mean Vote (PMV), sitting and standing reference height, indicates that MRT has a high effect on PMV. Solar position effects on MRT, and PMV of the terrace as an opened area has 0.6 points lower than the other zones. In the hottest time case, 0.4 points of PMV higher are experienced by the west sides of the main room due to the porous wall. Closed indoor zones, leading, and additional rooms have similar performance in providing thermal comfort. There is no door; the inter-zonal effect occurs. The terrace, opened area, gets over 50% of the comfort period, and it is similar to wind speed with outdoor, better ventilation (Figure 3). The additional room has scattered temperature for a particular time where heavy activities in the morning and the evening. All passive methods on existing design will still potentially direct the low-income house as verified findings from the past [17].

![Figure 3. Hourly temperature condition along a year.](image)

3.4. Cooling and heating loads and elemental breakdown

As illustrated in Figure 4, in the hottest month, October (included November), get total heat gains all the days/30-31days (Fully cooling loads). It results in not only the highest temperature but also the highest cooling loads. The hottest month has both Degree-Days and heat gains when the coldest month (August) has only the lowest in Degree-Days, not in heat gains. Meanwhile, the coldest time (Month) is indicated by the lowest temperature on average, not in cooling load. A high indoor climate characterizes it for a long time. The regression trend line, $R^2$ shows almost scattered (0.6), although it tends to increased cooling loads, consistently indicating a significant difference between the hottest and coldest months. In general, higher heat gain is not always experienced in a long time. It supported the prior results on green building suggestions for affordable housing [8,18].

The internal gain, caused by human activities and electric appliances, and conduction heat transfer, also has a strong effect on the cooling loads to make adaptive comfort [14]. On the other hand, although the lowland environment has a high mean radiant temperature, direct solar radiation makes only a small contribution (Figure 5). Compared with the other elements, sol-air (indirect/diffuse solar radiation through opaque elements) is an aspect of the cooling load that affects the energy efficiency the most for a cooling load requirement. The radiation has a high contribution, a minimum of large openings, and none of the transparent material makes the wall/roof re-radiate solar radiation. Meanwhile, the ventilation from a porous wall also has a small effect on heat gains/losses because of the indoor environment's low air movement.
4. Conclusion
For promoting livable and affordable urban housing, this study evaluated traditional tropical houses' energy performance using the Ecotect Analysis program for cooling load analysis based on field study data. The sustainable method on wind speed reductions from past to present, from rural to urban terrain roughness, affects design adaptation, particularly in building ventilation. Therefore, the occupancy style and controlling the building's opening location and material properties can improve the existing adapted structure in a changing environment. The more challenging activities (higher internal heat gains) result in a more significant influence on indoor temperature than frequent activities. In addition to Mishra and Ramgopal's findings [3], the preserved energy-efficient strategy in using natural materials and sheltered ventilation meth of traditional lowland houses with cultural and image respect has high potency for solving the cooling loads' problem in the disadvantage of the environment condition. Indeed, energy efficiency can be achieved without changing the traditional image. This study's future work will compare the highland built environment with this lowland building performance. All potential livable buildings can participate in this rural design and the gap connector between sustainable and affordable housing [19]. Furthermore, the adaptability of tropical sustainability could be improved by proposing a comfort range of thermal comfort through minimizing energy consumption on affordable housing.

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