Reinvigorating local building envelope for translated modern building and changed environment

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Abstract. Different from the past, there is a current higher density of buildings resulted in less horizontal ventilation. However, a high-density environment still provides an opportunity to control solar radiation by providing shading, both at the site and on the building scale. Traditional buildings have climate as form modifier. Social and cultural aspects influence the building and as consequences the local material has also evolved to be part of the modern building in an urban area. This study reinvigorates local material in adapting to the changed environment in Surabaya as the lowland area and Malang as the highland area because of the availability of the survival building in the largest city. The field study was undertaken to identify and to evaluate the real conditions of a building envelope surface by daily measurements. An infrared thermometer was used for field measurements of the surface temperature with an additional check for the moisture content of the material with a moisture meter and solar radiation with a solar power meter for surroundings condition. Results of this study revealed that the lowland house had better material performance in controlling the climate by reducing the extreme condition than highland performance. The overhang and terrace as transitional space were able to reduce the number significantly, more than 1500 W/m\textsuperscript{2} of daily solar radiation. In general, the problems of tropical houses were due to not only the frequency of receiving of solar radiation penetration but also the insufficient site shading to the building material.

Keywords: local material, modern building, surface material temperature, urban environment

1. Introduction
A tropical climate is characterized by relatively high temperatures and humidity. Physiological cooling is achieved from a lower wind speed to reduce heat accumulation and to increase the dehumidifying process. Cities, however, have limited space for accelerating wind because of the high density of buildings. This strategy can be harnessed to allow sustainable site planning of high-density environments, both building and human activities where solar insolation on facade simulation to assess urban typologies were very important [1-2]. The surfaces facing abundant solar intensity, East and West, have the highest insolation values [3-4]. Generally, these values increase at the upper levels of the surroundings because there are less shading from the neighboring blocks.

Traditional buildings have climate as form modifier; the building was influenced more by social and cultural aspects. On the other hand, the method for controlling the environment has been passed down through generations with improvements made from one generation to the next. In the tropical regions, the traditional building was designed in rural or open flat country terrain because of the low building
density. Recently, these buildings have been constructed in various places, such as urban areas. A high-density environment controls solar radiation by providing shading even limited access for air acceleration [7]. In an urban area, because of the ecological and energy efficiency reasons, the local material from the traditional building has been adopted for the modern building in an urban area. However, the adaption of local building material to the variation of the environment and its orientation has not been found in the previous studies [1-6]. Therefore, this research reinvigorates local traditional material in adapting to the changed environment for today’s building.

2. Methods
This study examined two topical urban areas, Surabaya (7.2°S, 112°E, 3 m above mean sea level) as the lowland area and Malang (7.8°S, 112°E, 575 m above mean sea level), as the highland area because of the availability of the survival local buildings in the largest city in Java Island, Indonesia. The field study was conducted to identify and to evaluate the real conditions of a building envelope surface by daily measurements on solar radiation, moisture content and their effect on surface material temperature (Table 1). The buildings were measured using the same methods: location, tools, and time. Each manual measurement was taken for approximately 3-5 minutes to have a consistent read value for every tool because the condition can change easily. The data collections had the free condition of a sensitive sensor with the height location, such as 1.5-1.7 m of height for outside/inside walls, 0 m of height for the floor and 2.5-3.5 m of height for gable (Tutup Keyong) and the roof parts (Gajah and Emper). Furthermore, Ecotect Analysis Program was used to verify and to estimate the results of field study. Figure 1 presents the profile of a building envelope in detail. The orientation rule was set with 0° as the South orientation and applied counter-clockwise. The traditional Javanese houses in both lowland, and highland regions were evaluated with the same object as thermal assessment. All materials used by a traditional building were recognized as lightweight materials.

![Diagram of building envelope](image)

**Figure 1.** Object measurement and profile.
Table 1. Field measurement tools.

| Tools                        | Specification                        | Location         | Time            |
|------------------------------|--------------------------------------|------------------|-----------------|
| Infra-red/No-touch Thermometer for Surface Temperature | Measurement range: -20°C–537°C, Emissivity: 0.95, Field of view: 12:1, Resolution: 0.1°C, Laser power: <1 mW | 1.5-1.7 m of height for Outside/Inside Walls, 0 m of height for Floor and 2.5-3.5 m of height for Gable and | 7 days/3 times a Day: Morning (06:00-08:00), Afternoon (12:00-14:00), Evening (17:00-19:00) |
| Moisture Meter for Moisture Content | Range: 0% to 90%. Accuracy: ±0.1% | | |
| Solar Power Meter for Solar Radiation | Range: 0-2000 W/m², Accuracy: ±10 W/m² | | |

3. Discussion

3.1. Solar radiation effect on local environment and building

A building shading simulation using Ecotect Analysis was taken to identify the existing environment. Site shading gave a description of the percentage of surrounding buildings and tree shading (overshadowing) as well as the shading by their own elements (building shading). By running this program, the solar radiation distribution effects were also analyzed. A calculation of the building envelope performance, building density and its effects on the building temperature were calculated for all times of the day and followed by a surface temperature calculation, especially for un-shaded surfaces. In addition to Maestre et al [3], some factors are important in the solar control by shading such as different overhang and side fin typologies, latitudes of building region, orientations for shading device.

As shown in Figure 2, the percentage exposed area of the lowland site was taken in the range 06:00-18:00 and 1.50 m of height as a human standing reference. The total exposed area was indicated by the un-shaded surface of buildings and vegetation and it gave a chance for heat accumulation into the buildings. Traditional tropical house as a building object had less than 10% of the exposed area in the South, and half of the East and West. The Northside received solar radiation penetration of more than 50%, especially for the terrace of buildings because there is open space located in this area, without any protected wall. This condition was affected by the long distance of the surrounding buildings and trees as environmental shading compared to the high angle of the solar altitude and solar azimuth location in the North area.

With the same simulation time, the highland house shows slightly different performance. Different from Hii et al and Chow et al [1-2], the Western area had less than 10% exposed area, the South and North received half of them in more than 10% of the exposed area. The Eastern area had more than 50% exposed to the solar radiation because of the un-shaded environment by both the surrounding buildings and trees, even though the solar position was the same as that with the lowland house. The un-shaded or exposed areas of the neighborhoods’ area had the problem of global irradiance of building envelopes. On the other hand, these open spaces still allowed wind acceleration into the buildings. In detail, Figure 3 shows the effects of environmental shading on the building envelope surface.

The roof elements of the lowland area received more than 1500 W/m² of solar radiation daily, whereas the building envelopes receive up to 800 W/m², such as the Eastern and Western Walls (Figure 3). All areas of Northern and Southern building envelopes were shaded, so the solar radiation received was less than 500 W/m². The 0.5 m length of the roof overhang in the East/West areas was too short to protect all parts of the wall. Therefore, only the shaded upper part (Tutup Keyong) received less than 500 W/m². The lower part of the terrace (<0.8 m), which appeared in the left of the Western Wall or the right of the Eastern Wall, received more than 100 W/m² because there was no wall as a protector. This condition caused a problem of heat accumulation in only sitting activities, while others activities might still have a possibility for thermal comfort. Furthermore, the terrace provided protection for
openings from solar penetration.

![Figure 2](image_url)

**Figure 2.** Site percentage exposed area in the range of 06:00-18:00.

![Figure 3](image_url)

**Figure 3.** Average daily radiation in the range 06:00-18:00

With a higher solar radiation value, the building envelope in the highland environment had higher global irradiance. With the same condition of the roof element (>1500 W/m²), the Northern Area received solar radiation from morning to evening. In addition, the back wall, North Wall, received high solar radiation, especially for the back opening, which had the same value as the roof, i.e. very hot. On the other hand, the wall still received less than 800 W/m². The front area, South, side wall and opening were protected by the terrace. The solar position in the Northern side gave an advantage. The East and West had similar characteristics to the lowland house (shaded upper part of the wall is colder/lower value). However, the value of global irradiance was higher, approximately 700-1000 W/m² for the unshaded part of the wall.

### 3.2. Surface material temperature condition

The surface temperature measurements in lowland showed that on the first day, it was disturbed by rainy and cloudy conditions. As shown by Figure 4, the lowland lowest temperature of all building envelopes was influenced by accumulated clear conditions after rainy or cloudy periods in the first day of the measurement, which made the environment cooler before sunrise. On the other hand, the second
day was the hottest day for the most of building envelopes because this day was the first clear day after the rainy condition on the first day, which allowed solar radiation to penetrate the building easily. The building roof normally had the highest surface temperature because its position is perpendicular to the sunlight. On Day-06 also, the Western outer wall had the highest surface temperature. This was influenced not only by the accumulated clear condition but also by the afternoon field measurement time (July), in which the azimuth of the solar position was 186° to 239°. Therefore, the South-Western elements, including the West wall received more solar radiation than others.

Figure 4. Measurement results of surface material temperature.

The direct solar radiation in the highland region, as indicated by the clear sky condition affected the highest temperature in the afternoon of most of the outside walls, except for the East Wall despite being under a clear sky condition (see Day-05). The highest temperature of East Wall occurred in the morning because clear sky allowed high solar radiation to penetrate the building envelope. In contrast, the cloudy sky (Day-06) affected the lowest temperature in the West Wall. For the same reason, in the morning of Day-03, the East Wall had a higher temperature than the roof at all times. In addition, the sky conditions changed from clear in the afternoon to cloudy evening. The surface temperature of the lowland and highland areas indicated that highland area had higher maximum temperature, but lower minimum temperature than the lowland area; the maximum was the roof in the afternoon of Day-05 with 53.0°C, while the minimum was the roof in the Day-03 with 19.9°C. The extreme condition of the highland region, particularly the roof element, could be affected by the higher global irradiance than the lowland region and the other elements of the building envelope. In general, the lowland building material had better material performance in controlling the climate by reducing the extreme condition than the highland has.

Based on field study above, to identify the local material, this study also results in the analysis of moisture content of critical building element, roof. Addition to Li et al [8], its relationships to temperature is the important factor which affect local material’s thermal and moisture stress (TMS).
As presented in Figure 5, the higher surface temperature of material for all environment is affected by the lower moisture content, dealing with air temperature and relative humidity relationships. However, traditional clay material with Rso (surface resistance) is lower than its conductance (fo), it is not capable of resisting the peak high solar radiation in the daytime (see also Figure 1). As consequences, the surface material is very high when the moisture content is still in high percentage because of the high clay material porosity. Therefore, the role of wood walls for all orientation where the surface resistance is higher than the clay roof has. It is expected to have a capability of controlling the lower angle of solar radiation penetration. Potential roof material and its construction which is adjacent to accelerate the air movement has contradictory treatment in controlling solar radiation in the peak of the day [9-10].

![Figure 5. Moisture content and surface material temperature relationships of the roof.](image)

3.3. Building envelope performance for translated modern building
The highland global irradiance was slightly higher than the lowland area. This was affected by the higher solar radiation, even though the time calculation was the same in the coldest month for every location. The higher altitude affects the higher value in receiving solar radiation throughout the year. An analysis of the wall and roof surface temperature (Ts) includes the outdoor temperature (To), solar radiation intensity (I), and the properties of material (αtotal) in addition to surface conductance, as shown by Equation 1.

\[
Ts = To + \left(1 \cdot \frac{\alpha_{total}}{fo}\right) \cdot I
\]

The high solar radiation throughout the year of tropical regions brings on the requirement for a shading design. On the other hand, some traditional buildings have been designed without a properly shaded wall. In this case, the roof is the critical element which has direct contact with solar radiation, except for providing environmental shading to the roof. The data show that the surface temperatures of a particular condition are the addition temperature of the outdoor air temperature for all building envelope elements. Therefore, the highest and lowest global irradiance also has the highest and lowest surface temperature, and if they are shaded, the surface temperature will be the same as the air temperature.

As shown in Figure 6, the lowland’s lower roof slope part, front Emper, had a peak value of 51.6°C at 12:00, whereas the lowest element, the back wall, had a peak temperature of 30.2°C. The back wall as the South wall had surface temperatures that were the same as the air temperature all the days, because
building envelopes were always shaded. Therefore, the peak temperature was not normally observed at noon but at 3pm (31°C). This also explains why the Western Wall, left wall, has a higher surface temperature than the Eastern (right wall). The Western wall had a peak temperature of 51.7°C at 4 pm. This even exceeded the front Emper value, which had the highest global irradiance. The Eastern wall had a peak temperature of 46.8°C at 08:00 am. In contrast to what happens with the lowland area, the highland building envelope still had back Emper as the highest value, even though it was only slightly different. This area had a peak temperature of 49.7°C at 1pm compared to 49.4°C at 4 pm for the Western Wall, whereas the Eastern Wall has a peak temperature of 43.1°C at 8 am.

Considering the modern building design, the detail of heat transfer is important to identify the capability of controlling changed environment from rural in the past for traditional building and today’s environment for newer one. Figure 6 shows the conduction heat transfer of the highest surface temperature, wood wall, for both in lowland and highland. In addition to relevant previous findings [11-12], low-energy modern building design could be generated through local material composites. The data were taken from measurement combined with its thermal properties. Meanwhile, the calculation was conducted by Matlab-GUI programming [13]. The heat transfer resulted in the same pattern of both locations with different level of temperature in 1080 s (0.3 hours of wood’s time lag). It indicates that in about 0.01 m thickness (1 cm) only, the wood wall has a capability in insulating the heat from outdoor depended on its outdoor temperature.

**Figure 6.** Potential material for future building.

4. Conclusion
This paper investigated the environmental and building to control the solar penetration into building using field measurement analysis, simulation program, and calculations for the traditional tropical building. In addition to existing findings [1,4], the surfaces facing East and West had the highest solar insolation values. However, in this research the problems were due to not only the frequency of
penetration of solar radiation, but also the limited of neighborhood (site) shading, both by building and tree. The high solar radiation, 500 W/m², was still reached by the only short size of roof overhang (lower than 0.5 m). The terrace was one of the worthy solutions for both lowland and highland houses in reducing solar radiation into building. The orientation of the building was one of the critical factors for the walls in receiving solar radiation, daily or annually even though it was the low-rise building which had a roof as the largest area. Furthermore, the traditional house had sloped roof and separated with different orientation. Thus, the smaller angle of the roof in the Northside had a higher surface temperature, both lowland, and highland.

It recommends that the exposed aperture in highland needs protection from solar radiation with landscape, vegetation or site shading, and building shading by overhang or terrace as transitional space. This strategy will be effective to reduce of the over 1500 W/m² of daily solar radiation. By this evaluation, it could deliberately translate modern from traditional, from local material for global requirement have potential reinvigorated richness of culture for natural respect by the ecological and energy efficiency reasons.

In the near future, this study will extend to review the potential thermal properties integrated with the other critical urban issues, noise, and the adaptation for future building design. Furthermore, it will be integrated with controlling both noise, and thermal environment to give guideline recommendation.

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