Evaluation of Outdoor Thermal Condition in High Density Settlement at Sade Traditional Village

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Keywords: Outdoor Thermal Condition, Thermal Comfort, High-density Settlement, Sade Traditional Village

Abstract: Thermal comfort depends on the macro and microclimatic conditions of the surrounding environment. To a large extent, the climate temperature condition is impacted by high-density settlement. One of the areas addressed in this study is Sade traditional village, it is one of traditional settlement that has a dense pattern of the building and located in hilly areas with a linear grid pattern. However, the cooling temperature process is significantly fast compared to a highly dense building in low altitude areas. In particular, this paper presents an evaluation of outdoor thermal condition at the high-density settlement in order to know the causal relationship between mass and building composition on the residential scale versus the outdoor thermal condition. The simulation method is used to analyse the research location using ENVI-Met software. Temperature, wind speed, and humidity are parameters being investigated in this case. The result revealed thermal comfort is quite constant and on a normal threshold; Temperature: 18 ^{o}C - 25 ^{o}C, wind speed: 0.5 m/s – 0.8 m/s, humidity: 68 %-74 %. Tightly building configuration and minimum of vegetation, influence on the rising temperature in a day, it makes a relatively fast evaporation process. The narrow distance between the grids makes the wind speed more increasing and accelerating the cooling process of temperature.

1 INTRODUCTION

Thermal comfort is determined by the physical environment, such as air temperature, relative humidity, wind speeds. These three factors have interrelated relationships to achieve thermal comfort. In humid tropical climates, the buildings are generally designed with a natural memorising system that maximizes the quality of temperature and humidity to be able to cool the building structure or the achievement of thermal comfort. Some factors of building and environmental influence are the position of building against the environment, the orientation of buildings, the layout of the mass of buildings against the direction of the sun and the direction comes to wind. One factor of the comfort of residents can be achieved by observing the layout of the mass and density of buildings (distance between buildings) and the influence of barriers, both vegetation and buildings that resulted in declining quality of the avoidance of the building Because of the insisting influence in an area. "Building density", the immutable influence in an un-possible area is the cause of the underachieving Comfort. The high density of buildings will increase the level of resistance to wind energy consumption, as one natural energy to achieve comfort ". The phenomenon in the study site is that the buildings are organized in a tightly lined and dependent on the existence of existing roads so that the temperature, humidity, and wind speed in a traditional village of Sade need to be further researched to know by correct density of buildings determined by the distance between buildings affects the thermal comfort. Based on the description, the traditional village settlements of Sade have a mass-based layout. Based on the layout of the time, the behaviour of the wind has varying flow patterns and speeds depending on the distance between the building and the state of the existing road. In this case, it can affect the quality of natural aspiration performance of the settlement as well as physiological comfort of the resident. Building density is influenced by the distance between buildings, building height, and building dimensions. These three conditions affect wind speed, temperature, and humidity. But in the case of Sade traditional village house dimension of building and building height are all the same, so that distinguishing factor is only the distance between buildings. In this study, it was devoted to research thermal comfort in

Susanti, E. and Damayanti, D. P.
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DOI: 10.5220/0013056600002836

In *Proceedings of the 10th Architecture Research and Design Conference (AR+DC 2019)*, pages 55-59
ISBN: 978-989-758-767-2; ISSN: 3051-7079

particular the influence of building density and pattern mass.

1.1 Selected Area

Sade traditional village is located at Rembitan Village, Pujut Sub-District, Central Lombok District, West Nusa Tenggara Province. The overall area is 7.340 m^2 and altitude 115 m above sea level. The orientation of the village led to the West-East, facing the direction of the sunrise. Sade Village located on hilly areas with even and wavy topographical conditions. Climate conditions at this location tend to dry in the dry season. The character of the ground surface is dry and barren. The characteristic of Sasak architecture dominated from building until the arrangement of the settlement. The area built of an entire village is 2.997 m^2. Population and density are pretty high while there is no territorial expansion and development remained concern on these areas. The percentage of area built of about 40 % consists of 120 mass of building and village's street. The average volume of the building varies 38 m^2 – 48 m^2. The Settlements use grid patterns, clusters separated by linear village's streets. Building conditions are quite dense, generally building at Sade village uses thatched as roof and bamboo woven as wall. The street is the only open area on this village. The streets are mostly covered by ground surface shielded with concrete paving material. Regarding vegetation, there are only few large trees with medium density on the entrance of the village.

2 METHODOLOGY

Simulation was chosen as a method for its reliability in investigating the causal relationship between mass and building composition on the residential scale against the outdoor thermal condition. The research location was analysed by ENVI-Met V3.1, and the parameters such as temperature, wind speed, and humidity are evaluated. Calibration between measured and simulated data are aimed to increase the reliability of the result to perform predictive study on high-density effect to thermal performance

2.1 Selection of Typical Day

Based on the last 10 years macroclimate data from the Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG) of West Nusa Tenggara, indicating May is the transition between the hot to the cold months. The maximum temperature has begun to decline to the minimum temperature. Minimum temperature occurs between June and August (dry season). For the West Nusa Tenggara region, an average of air temperature in a year is 26.5 °C and an average humidity rate is 82%. In May, the average temperature of the last 10 years reaches 26.7 °C, the average wind speed reaches 4 m/s and the average of humidity reaches 83%. Simulation timing is adjusted to the retrieval of field data so that the data is more valid and know how much the difference between simulated results and field measurements. Accordingly, this study selected the day of May 12 as a simulation day. From this BMKG data, will be used as an input simulation program on the ENVI-Met software V-3.1. The simulation is done for 24 hours to know the fluctuations that occur in accordance with the running process on the software Envi-Met V-3.1.

2.2 Characteristic of Settlement Model

Modelling simulation on ENVI-Met has different grid settings on each model according to the extension of the area to be simulated. Area of Sade Traditional Village is 7.340 m^2 with a build area of 2.997 m^2. The village has communal typology, with the same typical and compact housing. ¼ of the build area will be used as a representation, with the simulation area is 749.3 m^2. The surrounding environment of buildings and vegetation in the settlement are in accordance with the actual condition, to determine the impact of environmental conditions on the overall thermal performance of the settlement. There are modelling simplification for the curve-shaped building. The shape of the building is interpreted with a beam whose outer size can be adjusted so that the shape becomes simpler. While the size of the grid can only simulate with integers, it is necessary to do the simplification of numbers close to the actual number. Basic parameters that will be input and transition existing condition to the simplification of modelling according to the capacity ENVI-met simulation can be seen in the Table 1.

Table.1 Simulation model of sade traditional village using Envi-met

Simulation Input Parameter	
Location	Rembitan Village, Pujut Sub-District, Central Lombok District, West Nusa Tenggara Province. (S 8°50'3.53" E 116°17'39.12")
Simulation Day	12 Mei (hot day)
Simulation Duration	24 h, from 6.00 am to 06.00 am
Grid Dimension	2 x 2 x 2 m
Grid Size	68 x 68 x 20
Average building height	5,5m
Transition Model	

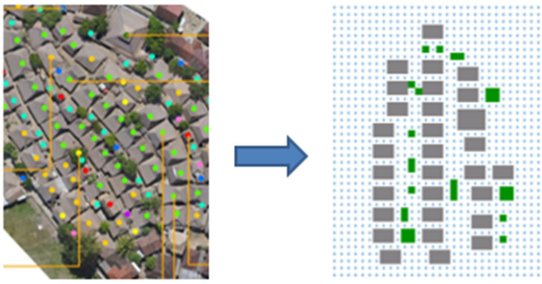
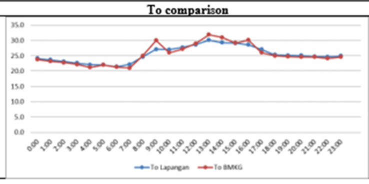


Table 2 To profile from BMKG the past 10 years and To field measurement

Location	To comparison
Sade Traditional Village, West Nusa tenggara	

2.3 Climate Data Verification Stimulation and Measurement Result

The macroclimate in West Nusa Tenggara Province is used as input in the simulation process in this research. To what extent the compatibility of thermal performance between simulation and measurement in real condition, in order to study and intensify the understanding of the deviation in these two data results. In general, thermal data of specific building is verified by comparing outside temperature based on real condition and outside temperature from BMKG in the past 10 years (micro climate simulation results).

The comparison on To was made for Sade Traditional village in West Nusa Tenggara. Based on the comparison the average outside temperature for West Nusa Tenggara reached 25.4o C, whilst average temperature data obtained from BMKG in the past 10 years show 25.3. The disparity for average temperature is 0.1o C, whereas at the highest temperature day the difference is around 1-2o C. As can be seen from Table 2 To profile from field measurement and BMKG in West Nusa Tenggara region have a similar curve.

In examining building performance, the main focus in this research is on thermal comfort produced by the building. The comfort condition range on sensory level known as neutral temperature. Neutral temperature is a thermal condition when a person does not feel heat nor cold. The equation to determine the neutral temperature is Tn = 17.6 + 0.31 x Tav, Tav is average temperature outside in a month when the measurement is performed. This data obtained from BMKG data record and it acquired that Tav value for Sade Traditional Village is – 26.7 ºC. The comfort range is taken from +2 °C above and below neutral temperatures (Tn) (De Dear, R. J, and Auliciems, 1985). For micro-climate in Sade Traditional village, the value of neutral temperature is Tn = 25.9 °C.
At table x.x the maximum difference is up to 4 ºC at 12.00, while for the overall average difference of only 1.2 ºC. This difference is affected by the contour of the ridge, vegetation, overall density settlements and climate conditions fluctuation. The condition mentioned above causes change temperature influenced by the environment outside of the courtyard. Comparison with the results of the Tn counting, thermal comfort limit of 29 ºC and a lower limit of 24 ºC. The difference in field temperature range with BMKG is still included in the boundary of outdoor temperature deviation tolerance, therefore, the outside temperature data (To) BMKG can be used to present the actual To condition in the field with relatively small fault levels

3 RESULT AND DISCUSSION

3.1 Outdoor Thermal Condition

There are three Envi-met simulated time scenarios, represents morning, afternoon and evening conditions. Orientation, the ratio of buildings to land area, and the typological pattern of settlements impact how wide the surfaces being exposed on solar radiation. Sade Traditional Village is oriented west-east, so it will be exposed fully to the sun during the day and tends to be shaded in the morning and evening. Figure 1, contrast in shades composition shows the temperature change pattern, in which rises from morning to evening. The dense of mass composition of settlement, make a slight surface exposed to solar radiation. In the morning temperature increase tends to be slow due to shading occurring. At 08.00, the average outside temperature of the building (To) is about 18-20 °C. In west orientation is domination by orange shades. Solar radiation affects the increase of outdoor temperature in this area. On the other side of the settlements in the dominance of green shades that shows the low temperature in the settlement that is not exposed to solar radiation. Grid mass patterns cause shading in the unexposed part of sunlight. At 12.00 The Sun is right above so that the surface can be exposed to more sun. The temperature rises up to 3 °C with an average of about 23-25 ° C. there is minimum vegetation around building and street so that many surfaces are exposed and slightly shaded area.

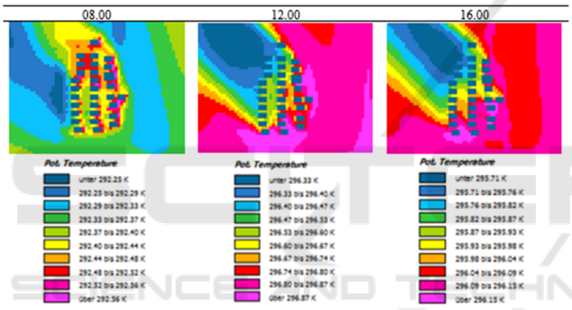


Figure 1. Outdoor Temperature of Sade traditional Village

The ground surface of the street will be fully exposed to solar radiation. It has the potential to raise the outdoor temperature so that the surface temperature is more dominant red and orange shades at settlement. At 16.00 the position of the sun begins to set, the sun-exposed area begins to decrease and the shading occurs. Settlements in the southeast are more exposed to the sun so it is dominated by red shades. In the afternoon, the process of heat release from the ground and building surfaces, the time lag of the heat release process is what causes the red shades more evenly.

Temperature averages around 25 °C, followed by slowly decreasing the temperature to the night. Temperature averages around 25 °C, followed by slowly decreasing the temperature to the night. For the high-density residential scale, resulting in the temperature is quite low. It is affected by the location of the hilly area and the linear typology of the settlement. The high density of the building on the Sade traditional village affects the shading factor and the number of surfaces exposed to solar radiation. These factors affect the thermal fluctuations generated on the macro scale in the entire village.

3.2 Outdoor Wind Speed Condition

The ventilation of the settlement is impacted by the building density as shown in Figure 2. The distance between the buildings is close enough, making the airflow tend to be static. Average wind speed in 24 hours reaches 0.33 to 1.5 m/s. The area around the building is dominated by blue shades with evenly spread, the wind speed is relatively low between 0.5 – 0.8 m/s. Sade Traditional village located in hilly area, and altitude 115 m above sea level. A linear settlement pattern and a lack of vegetation, enabling smoother airflow on unhindered areas of the building, especially on the village Street area that separates between clusters. Figure 2 shows at each simulation time, the village Street area is dominated by a green shades indicating higher air fluctuations. The average wind speed in this area is 1m/s to 1.4 m/s. Observed from the time change, wind speeds are decreasing from day to evening and will increase at night to the morning. Overall, the density of buildings in Sade village causes constant airflow and minimal turbulence. Grid patterns on settlements allow for air fluctuations, narrow village streets cause higher wind pressure and can accelerate outdoor temperature cooling.

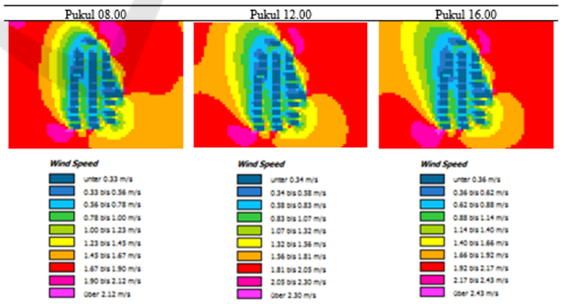


Figure 2. Outdoor Wind Speed of Sade traditional Village

3.3 Outdoor Humidity Condition

Sade Traditional Village is including in communal type settlement, the distance between buildings is quite tightly. Figure 3 shows the settlement dominated with green, yellow and orange shades at

08.00, heading 16.00 humidity is getting lower with dominated by blue shades. The shades distribution of isocontour represents a constant average of humidity ranging from 68 – 74%. Humidity in the all-day not increasing significantly. The higher the position of the sun, the lower the humidity. This is due to the tightly building configuration and minim of vegetation. Temperature increase and accelerate the evaporation process. The narrow grid on the settlement make wind speed more increasing and accelerate the temperature cooling process. Figure 3 revealed humidity cycle decreases in the morning to the afternoon, then rises back in the afternoon.

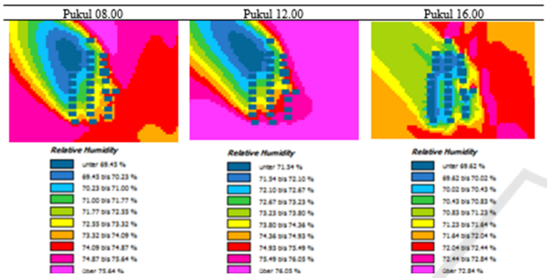


Figure 3. Outdoor Humidity of Sade traditional Village

4 CONCLUSIONS

This paper studies the causal relationship between mass and building composition on the residential scale with the outdoor thermal condition. Parameter focus on temperature, wind speed, and outdoor humidity condition. As it has been known from the results of field observations, Sade traditional village that has a dense pattern of the building and located in hilly areas with a linear grid pattern. However, the cooling temperature process is significantly fast compared to a highly dense building in low altitude areas. Simulation results showed, the thermal comfort is quite constant and on a normal threshold, as can be seen from several parameters such as; Temperature: 18 ºC - 25 ºC, wind speed: 0.5 m/s – 0.8 m/s, humidity: 68 %-74 %. At the middle of the day, a settlement is fully exposed to solar radiation, it can increase the temperature until 3 ºC. Surprisingly the airflow pressure is increasing yet on the open space area the distance between the buildings is close enough. The average wind speed in this space reaches until 1.5 m/s. It revealed a linear grid pattern on Sade Traditional Village plays an important role in enhancing outdoor thermal comfort. In addition, the location in the hilly area tends to be windier than the lowland, allowing for more wind flow so as to accelerate the air cooling process.

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