Climatic Significance of Colonial House Forms in Surabaya

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Abstract. The present study explores the morphological characteristics of colonial houses in Surabaya. Four houses are included as the subject, and physical features of the building are recorded through field observations. Basic drawings of the building are made and used for the morphological exploration. Formal and topological characteristics of the house are then analysed and its climatic response as well as climatic adaptation potentials are evaluated. Principles of climatic adaptation and findings from previous studies on the subjects are used as the basis of the evaluation. The study found that the colonial houses in Surabaya have a great potential in terms of climatic adaptation. Despite the compact shape, the layout of the building allows internal spaces to poses high connection to outdoors, and hence increases its degree of connectedness. The colonial houses show moderate degree of exposure and have high degree of porosity due to the configuration and size of windows and doors of the building. All of these formal characteristics contribute to the significant climatic response of the building.

1. Introduction

Formal and spatial characteristics of a building modify external environment, including climate. Building shape could determine the amount of heat gain and air flow pattern around the building. Spatial arrangement within the house could influence ventilation as well as light penetration. From the passive design point of view, these formal and spatial characteristics play a primary role in producing an energy efficient design.

Colonial houses in Indonesia have a specific morphological characteristic that embody both features of Indonesian traditional dwellings and Dutch buildings. Passchier cited in [1] considered the design as a hybrid architecture. The house appears in a relatively new form, which neither resembles Dutch nor Indonesian traditional building. Common features of colonial house are of a compact shape and has surrounded by abundant open space. The building is typically made of thick brick walls, and has large openings, big as well as steep roof.

Many studies regard the colonial house as having good climatic adaptation [2-4]. These studies, however, do not pay attention much on investigating spatial and formal characteristics of the building in relation to its environmental performance. Conversely the studies that focus on formal aspects of the design tended to explore only the formal characteristics of the building, such as shape, configuration/composition [5-7], without putting any specific reference to climatic conditions.

From a wider perspective, Dall stated all architecture is influenced by climate [8]. The reason for this is building is required to protect internal conditions and the building from negative impact of the climatic. Building shape and façade are important aspects in determining thermal condition of a
building [9]. Window’s properties such as size, orientation, and disposition will influence ventilation [10] and daylight condition [11] in the building.

The present study noted that aside from the fact that many studies have conducted over the last decade on investigating the climatic performance of a building, only a view of them paying attention on exploring climatic significance of colonial house form. Aim of the study, therefore, will be set in investigating morphological characteristics of the house in relation to its climatic adaptation. It will analyze spatial and formal characteristics of the building and evaluate its climatic response as well as climatic adaptation potential, especially with reference to the warm-humid climate of Surabaya.

2. Method

The present study explores the morphological characteristics of the colonial houses in Surabaya. Four houses are included as the subject, and physical features of the building are recorded through field observations. The houses considered in the study are located in urban areas, i.e. houses in Tapak Siring street (HC1-Siring), Nias street (HC2-Nias), Sutomo street (HC3-Sutomo) and Musi street (HC4-Musi). Area of the buildings is 132.4 m², 133.9 m², 152.2 m² and 205.1 m² respectively. For the study, only the original colonial house that were taken into account, and building extensions are excluded. Figure 1 shows elevation of the four houses.

2.1. Morphological measures

Basic drawings of the building, i.e., plan, and elevation, are recorded and used for the morphological exploration. Formal and topological characteristics of the house are established by using diagrams depicting wall adjacencies and accesses which exist on internal and external walls. Wall adjacency only considers walls that have a length of 1 meter and more, i.e., a dimension that enables window or opening to be incorporated on the walls. Wall access includes all existing openings/windows and doors on the walls.

Based on wall adjacencies and accesses diagrams, justified access graphs indicating relations between internal-external spaces, and degree of connectedness (DC) of the house is calculated. Other calculated measures are average number of adjacency and access of the building. The first is used to indicate degree of exposure (DE), and the second used to indicate degree of porosity (DP). The first indicator chiefly relates to thermal response of the building and the second relates to response of the building to daylight and ventilation. This method is adopted from Antaryama [12].

2.2. Analysis of climatic response of buildings

Climate analysis was first conducted to describe characteristics of the climate of Surabaya. The second is analysis on dimensional characteristics of the house. This includes window-to-wall ratio (WWR) and window-to-floor ratio (WFR) which are used to evaluate and indicate climatic response of the building. Climatic response potentials of the house were also analyzed on the basis of the possible use of wall for promoting daylight and ventilation. Basis of the climatic response evaluation is the Indonesian National standard (SNI) for the design of daylighting [13] and natural ventilation [14] as well as energy efficiency for building envelope design [15, 16]. This analysis is adopted from Ibrahim and Hayman [17].
3. Results and Discussions
Results of the analysis and discussion are arranged into three parts. The first describes climatic conditions of Surabaya. The second part explores the morphological characteristic of the house, and the last part evaluate the climatic response and the climatic response potential of the buildings.

3.1. Climatic condition of Surabaya
Average climatic conditions of Surabaya are obtained form the MET Office of Juanda, Surabaya. Figure 2 describes conditions of air temperature, air humidity, wind speed and direction, and solar radiation. The city of Surabaya is laid on 7.22° south of the equator and regarded as having warm and humid climate. Average air temperature (28-30 °C), solar radiation (up to 1200 W/m²), and relative humidity (76%) are relatively high, whereas wind speed is generally low (2.6-3.6 m/s). This condition indicates that the city experiences almost constant warm and humid conditions throughout the year. Wind, which can be utilized as a means of restoring comfort, unfortunately is not high enough for this purpose.

Figure 2. Climatic condition of Surabaya: air temperature (a), air humidity & rainfall (b), wind (c), solar intensity & sunshine duration (d)
The monthly rainfall is high (280-400 mm) and the sky ranges from partly cloudy to cloudy/overcast as indicated by the sunshine duration which is within a range of 42-85%. The sky characteristics could prevent heat dissipation towards the atmosphere and consequently could create uncomfortable thermal condition in the city. A care must be taken in order to prevent the building from gaining heat and excessive light, and to promote ventilation for restoring comfort in this type of climate.

3.2. Morphological characteristics of the house

Despite the compact plan shape, layout of colonial houses in Surabaya allows a great deal of internal and external accesses (figure 3a). Many accesses both internally and externally can be associated with good cross ventilation and sufficient natural light penetration. All the houses are designed in such a way that all internal spaces have at least one internal and external accesses. A two-row type of layout enables this characteristic.

Adjacency between internal spaces can be maintained into a high level in the design of the house, offering a greater opportunity for spaces to have internal connections. The same also applies to external walls where spatial configuration of the house could increase the number of external wall adjacency. Although this characteristic could increase the amount of heat gain, the availability of external walls however could also increase the number of opening/window on the building that are attached on the wall, and thus increasing airflow through the building and natural light penetration.

Observing the justified access graph of the house shown in figure 4, it can be seen that all of internal spaces in the building are apparently connected to outdoors. Some of the spaces are also internally linked. Degree of connectedness of the house is high (DC=0) indicating that all spaces are directly connected to outdoors and consequently the buildings have a great chance for external penetration.

![Figure 3. Diagram denoting adjacent and accessible walls in the colonial houses](image-url)
Colonial houses in Surabaya have relatively moderate degree of exposure (DE). As figure 5.a shown, the average number of external adjacency of the four houses under study is around 2. It follows that about half of the walls in each rooms are exposed to external environment. From thermal design standpoint, this characteristic could be associated with an increase in heat gain. Average number of internal adjacency ranges between 2 and 3. Two houses, i.e., HC1-Siring and HC4-Musi have low level of DE (2). Average of overall internal-external adjacency is between 4 to 5.

Degree of porosity (DP) of the house is high (figure 5.b). This can be observed from the average number of internal-external access which are between 3 and 4. This average number indicates that each space in the building has access in almost all its perimeter. Average number of external access clusters around 1 and 2, and average number of internal access is about 2 in all cases. This characteristic illustrates a great allowance for cross ventilation and light penetration.

3.3. Climatic significance of the house form
Response of building to thermal condition is evaluated on the basis of the value of WWR that meets the energy efficiency requirement, i.e., overall thermal transfer value (OTTV) of 35 Watt/m2. The method assumes that the building is air conditioned and thermal response of the building is determined by the heat gain through the building envelope. Despite the fact that the building is naturally

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**Figure 4.** Justified access graphs of the four house under study

**Figure 5.** Degree of exposure and porosity of the building
ventilated, the method is regarded as adequate for assessing the role of building envelope in modifying the thermal conditions. For the evaluation WWR for different building orientation is estimated using charts given in [11]. Figures 6.a and 6.b give results of the analysis.

The two figures show that in general the standard WWR can be attained by all of the houses. However, there are minor cases, such as in HC1-Siring and HC2-Nias, where the values are over the standard. The result implies that the colonial houses only transfer small amount of heat into the building, and thus it is able to promote energy efficiency. WWR of HC3-Sutomo and HC4-Musi in particular are all below the recommended WWR (figure 6.b).

From promoting ventilation point of view, it can be seen in figure 6.c that the external window-to-floor area ratio (WFR) of the houses is well above the standard (5%). As illustrated in the figure, the external WFR of the building lays between 15 to 25%. It follows that natural ventilation can be induced in the building. Internal WFR that ranges between 8 to 16% increases the opportunity for the house to have better cross ventilation. Comparing all the house, it can be seen that external WFR of HC4-Musi is the lowest (around 13.4% WFR). The values are slightly increase in HC3-Sutomo (17.8%), and then followed by HC1-Siring (19.1%) and HC2-Nias (23.7%) respectively. From this result, it can be said that climatic significance of all of the houses is high.

Similar results are found when analysing the ability of the design in promoting day light. As can be seen in figure 6.c, it is observed that external WWR of the houses are well above the standard (8%). This implies that daylighting can be incorporated in the design of all colonial houses without any big efforts. Thus it can be said that all the houses have high climatic significance especially in terms of daylight provision. Among the four houses under study, HC2-Nias in this case is the best.

![Figure 6. Climatic response of the building](image)

Climatic response potentials of the houses are shown in figure 7. From this figure, it can be seen that number of internal and external adjacencies is generally higher than internal and external access (figure 7.a). This follows that the house still has an allowance to provide daylight and ventilation if it is required, especially when the existing coverage area for light and wind penetration is reduced by obstructions such as overhang or neighbouring buildings. In terms of external access, the opportunity
is widely available in the four houses under study, however in terms of internal access, only in HC2-Nias that all allowances are already utilized.

Considering the overall access and adjacency in the building, it can be seen that similar tendency also occurs in the case of overall access and adjacency (figure 7.b). Allowance for providing daylight and ventilation in all cases is high. The results again underline the good climatic response of the building, especially for providing a more distributed airflow in the building. The condition particularly gives significant impact in restoring thermal comfort in the house.

**Figure 7. Climatic response potential of the building**

4. Conclusions
From the above discussion it can be concluded that under the warm humid condition of Surabaya the colonial houses have a great potency in promoting comfortable indoor environment in the building. The morphological characteristics of the house show this tendency. The high degree of internal and external connectedness (DC=0) and high degree of porosity (DP>5% and 8%) are indication that the house can offer sufficient access to natural ventilation and daylighting. Moderate degree of exposure (DE=2) and relatively moderate WWR (<35%) are also indicators that the building will transfer less heat through its building envelope. An allowance for further effort in promoting daylighting and ventilation actually exists, because not all of the available walls are used for openings/windows. It should be noted, however, such an allowance for daylighting or ventilation can pose a detrimental impact to the thermal condition of the building.

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