

# **TROPICAL-HUMID ARCHITECTURE IN NATURAL VENTILATION EFFICIENT POINT OF VIEW**

## **A Reference of Traditional Architecture in Indonesia**

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### **ABSTRACT**

Microclimate comprehension of building provide data about ambient architecture\*\*, because the role of climatology is very important in architectural design development. This paper deals with ambient architecture in tropical and humid region, the investigation of natural ventilation efficiency in traditional architecture in Indonesia. Investigation was carried out with comparative method of architectural opus in Java Island. It is selected on historical basis, started from Islam proselytization period until the presence of architectural performance that has been developing up to now.

### **1. INTRODUCTION**

Architectural design of residential building used to be developed by accumulated observation from immediate surrounding. Design without designer method passed on from one generation to the other. Conversely, contemporary design style that is developing recently tends to be more universal and ignores the nature and its environment (see mask caricature in Fig. 1).

Environment for human in the ancient time constitutes sources of life; this regulation has been prevailing. Traditional society gave us data about the relation between building physical performance and climate condition.

Researches about constituent component of climate in tropical-humid area (such as air temperature, wind, sun radiation and humidity) are needed to harmonize building and its surrounding nature.

The objective of this paper is to give explanation and description of tropical-humid traditional architecture history in tropical-humid region in Indonesia and the influence of technology progress on residential building design to solve environment problems.

It is the architects' job to cooperate with urban climatologists and related experts to bear a comprehension about microclimate of immediate surrounding before applying it on their design. To face climate problem, architectural parameters such as building orientation, window opening, roof shape, building performance and vegetation planning must be considered seriously. Climate modification is also effective to obtain optimal temperature in building.



**Fig. 1: Architecture must be seen also as a cultural process not only as physical product [1]**

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\*\* Sort of architecture field emphasizes the influence of climate on architectural design. It is the focus of study in CERMA laboratory and schools of Architecture in France and has been developing in many studies in other research laboratories such as CSTB – Nantes, famous for its wind tunnel.

## 2. CHARACTERISTIC AND TYPE OF ARCHITECTURE IN INDONESIA

Tropical-humid architecture means vernacular architecture located on tropical region, between latitude of 23° south and latitude of 23° north with high humidity. For this case, we discuss about Javanese traditional architecture in Indonesia. The location and type of traditional architecture are selected based on the influence of society culture on architectural performance.

In ancient time in Java Island, climate (tropical-humid climate) and cultural aspects (Indonesia society culture such as mutual assistance co-operation called "Gotong Royong") formed residential architecture. Ambient architecture factor could be seen on building appearance (indoors and outdoors) by using natural ventilation.

After viewing the type of tropical traditional houses in Java island and the analogy of Indonesia traditional houses, we found that Indonesia architecture was classified in three types of houses, they were: traditional, colonial and temporary houses [2]. Therefore, architectural aspect of Indonesia houses started from *the influence of Islam* (15-17 century), *the influence of European style architecture* (in 19-20 century) and *contemporary architecture* was investigated.

All residential building types were selected to discuss the efficiency of natural ventilation on residential buildings in tropical-humid area.

### 2.1 Type of Javanese Traditional Architecture

The first type located on Kudus (a town in central Java) that is famous for the central of Islam proselytization. The society obeys the rule of religion, and most of their means of livelihood are trader and entrepreneur. Religious activities are reflected on the use of mosque facility and yard mutually. These social and cultural aspects influence the daily activity and are reflected on building and environment planning [3].

The residential area has typical forms:

- First, it is indicated by mosque and its tower constitutes the central of society activity.
- Second, dense Javanese settlement (with or without fence).

The characteristics of interior planning are:

- Interior of a house consists of living room ("Dalem") that constitutes the central part of the building, kitchen ("Pawon"), veranda

("Jogosatru"), front yard, service room (well, bathroom) and building annex ("Sisir"). All parts are bounded by wall and wind blows through openings like window, door, and ventilation mesh. The interior arrangement tends to be linear on left and right sides of building and living room in the centre of house has the highest volume. It is good to provide direct and continuous air movement.

- The shape of roofs called "limasan" (consist of four aslant stretches), "joglo" (piles of two or three limasan roofs), "atap kampung" (two aslant roofs are connected firmly) and the combination of them are made of roof-tile and have clay carving ornaments on roof top (Figs. 2a and 2b). This shape has a high attic volume (about 2-3 fold of wall area) in order to ward off the sun radiation (indoor insulation) [4].
- Ceiling shape follows the shape of oblique roof, which is made of wood to enable air movement and heat lost on roof surface [5]. Ceiling on the central of the room is a thick heap of wood beam (called "tumpang sari" construction) as heat insulator for rooms because high ceiling position evokes higher room volume.
- Wind blows on attic that becomes heat insulation. In certain situation, it functions as a place for storing wealth of occupant.
- Wall is made of wood and full of carving ornament. That is an artistic appearance, besides its function as wall decoration, this woodcarving has meshes to provide airflow into building. Fig. 3 gives the details of meshed woodcarving type that fulfil building walls. This meshed woodcarving is also used in doors and ventilation mesh under ceiling.

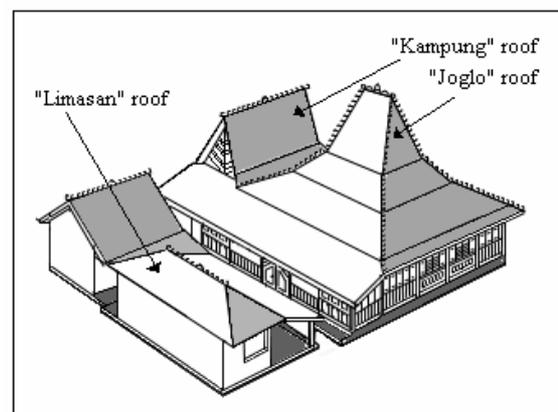


Fig. 2a: Roof shape of Kudus houses

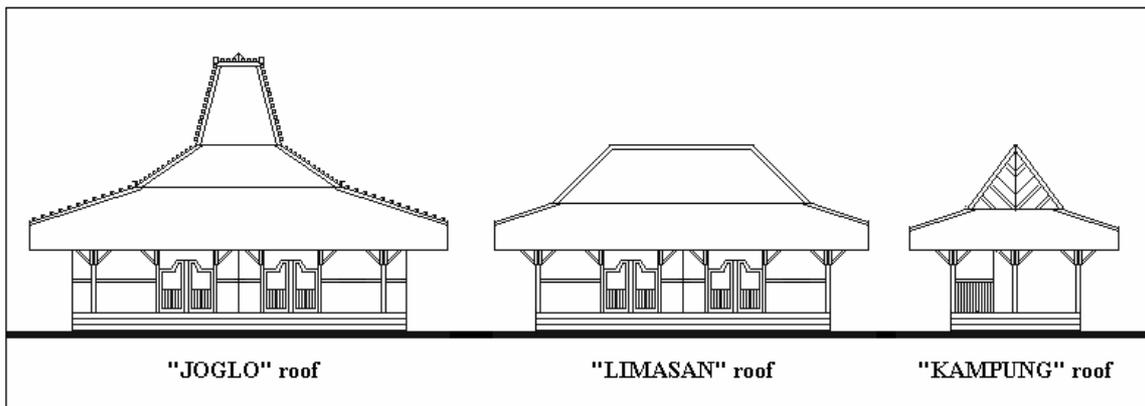


Fig. 2b: Front view of buildings with various roofs: “joglo”, “limasan” and “atap kampung”

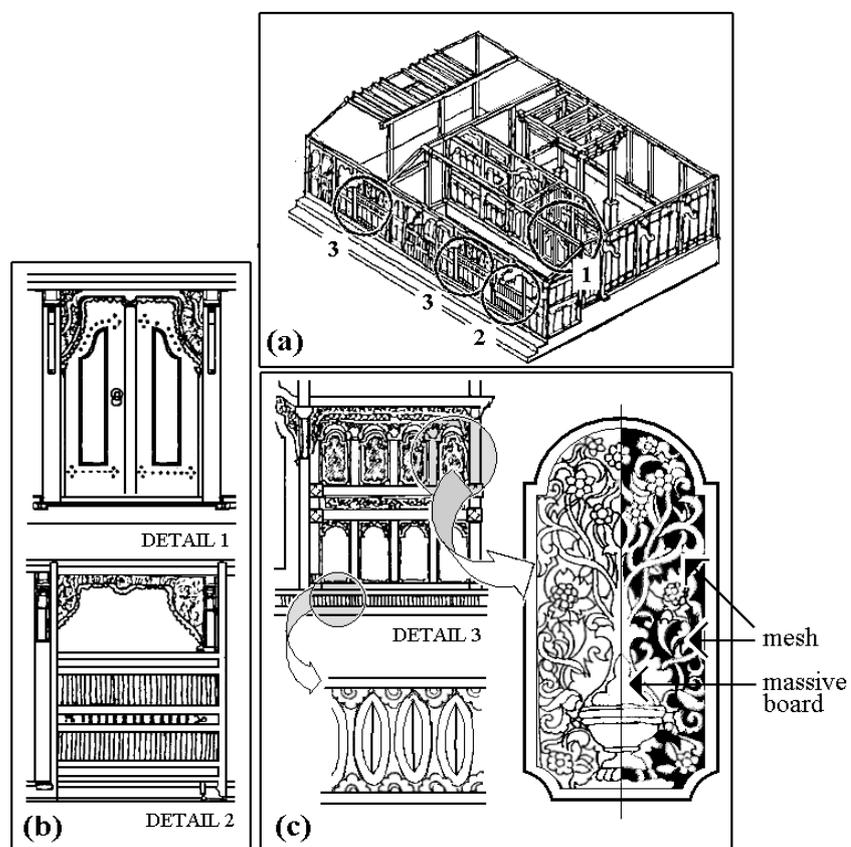


Fig. 3: (a) The use of wood on all building construction (b) the detail of meshed woodcarving on door and on wall and (c) ventilation mesh

- Stratified floor: begin with ground yard, and then veranda that made from hardened clay, and main room constitutes a wood scaffold to provide air circulation and remove the humidity of the ground.
- Curving and narrow paths between houses provide traffic lane for occupants and airflow course, also resist sun radiation and form a shadow area.
- Building orientation facing North-South (influenced by Hindu cosmology). It is a right orientation toward wind direction and deflects the dominant orientation of the sun in East-West.
- Kerosene lantern is used for artificial light at night; the use of electricity equipment is very rare except TV and radio.

- Javanese houses have yards of the same breadth as the building and planted by various vegetation. (Fig. 4). It functions both as an opening area in front of the house in order to make interaction or relation with society (social activity) and religious activity in family. On the aspect of air movement efficiency, it makes rooms become cool because wind blows into the rooms through the green area. Wind will reach indoor area smoothly, it is beneficial to the living room (living room floor is the highest part in the house and has high volume; its position is right on building axis).

## 2.2 Type of Colonial Architecture

Buildings of this type could be found in several cities in Java Island (such as Jakarta, Semarang, Magelang, Surabaya, etc). One of them is Semarang Old City (Fig. 5), which is popular with Emmanuel church («Gereja Blenduk»). Colonial architecture in tropical-humid area was different from European classic style, particularly in Holland. The European classic style could be seen from symmetrical building, un-plastered brick usage and rich of classical decoration like “cornice”, “oculus” and “amortizement”, etc [6].

There were three perspective principles of colonial architecture toward tropical-humid climate in Indonesia [2]. There were perception of wind, sun, and rainfall influences.

Construction elements were made to settle air movement and lightness problems and also rain protection, such as:

- Oblique roofs to tackle rainfall
- Paths around buildings function as heat insulation, building connection and shadow areas.
- High indoor ceilings with ventilation mesh above them.
- Having ventilation system and windows with large opening almost fulfil building walls.

Whereas, the use of other European elements was synchronized, like tower and arch. They had different functions as enjoyment to get lightness and airflow. These building were not designed for air-conditioner and electricity fan usage. All of the physical environment aspects have been considered and applied on building design.

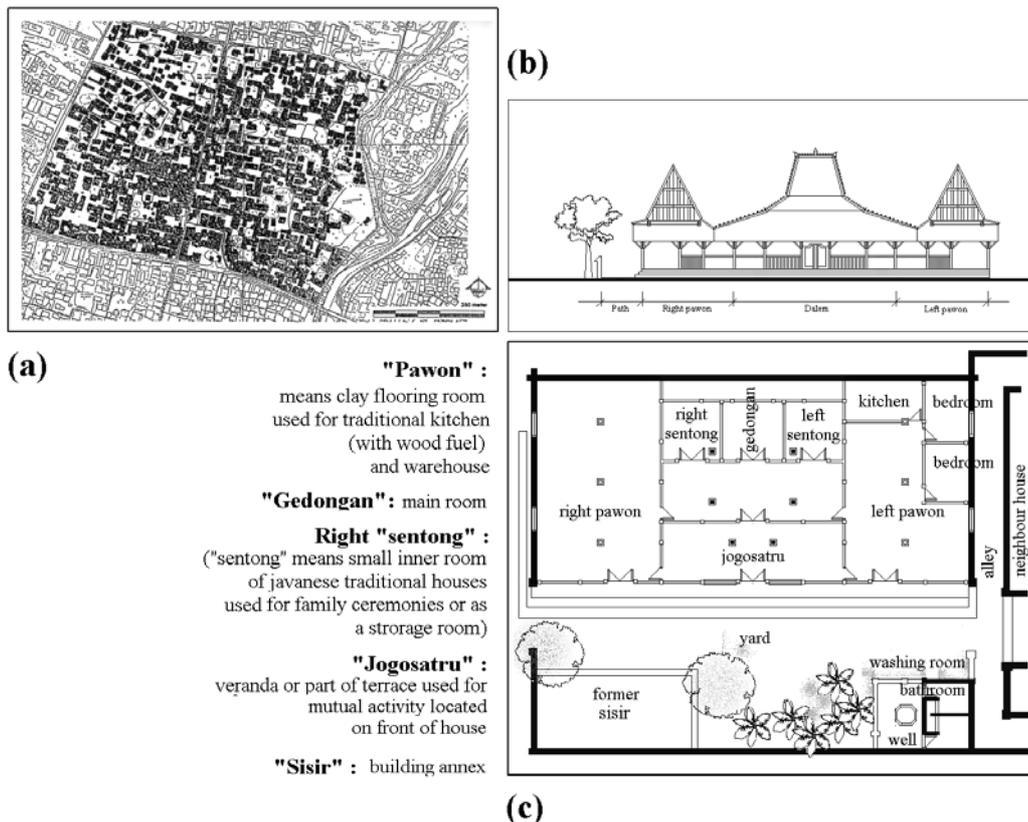


Fig. 4: (a) Buildings and its environment (b) building appearance and (c) room plan, garden and paths arrangement [3]

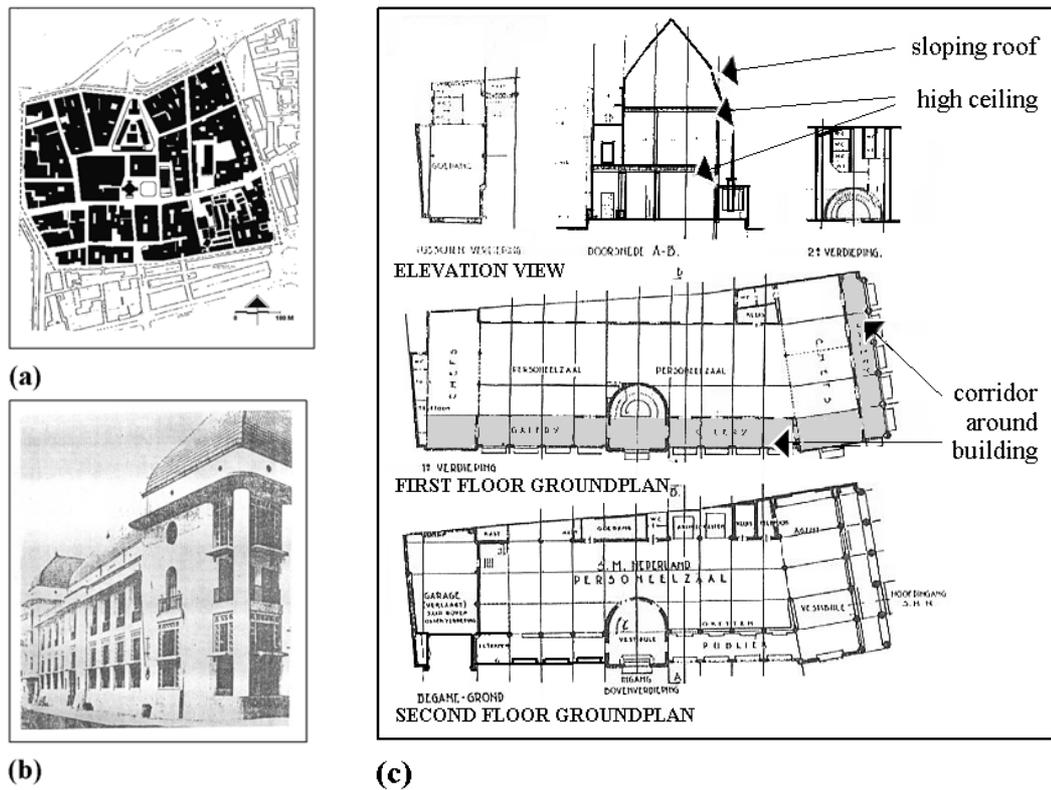


Fig. 5: (a) Block plan in Semarang old city area [6], (b) building appearance and (c) room plan with corridor around it and building structure shows attic height and building roof declivity [2]

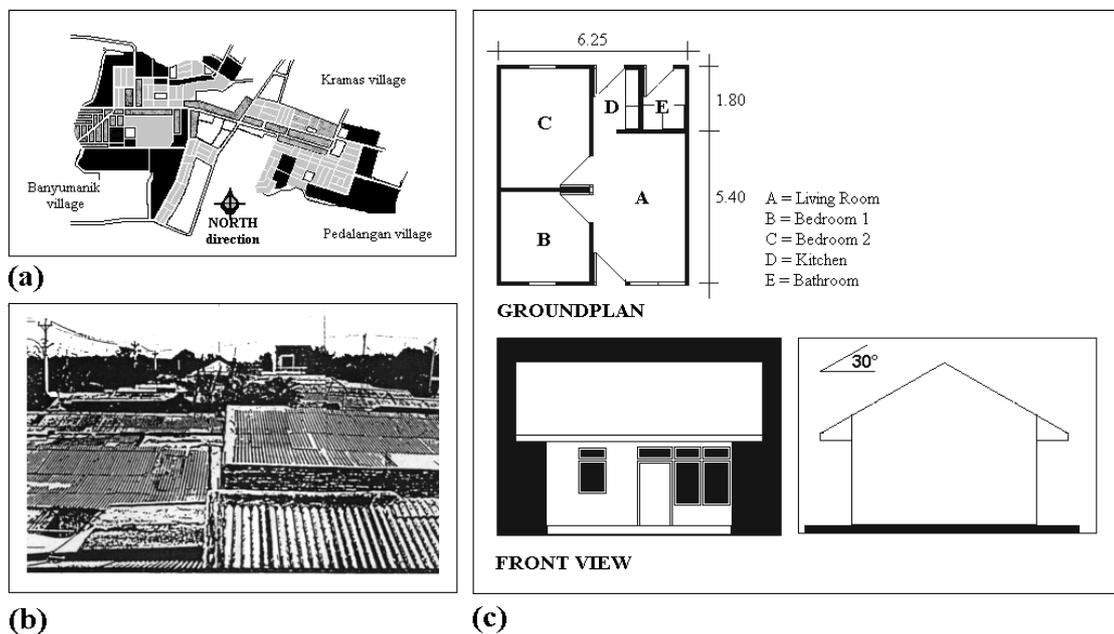


Fig. 6: (a) Situation in Perumnas Banyumanik (contemporary settlement), (b) roofs between houses show density in opening and developed spaces, as result of building development [7], (c) plan and building appearance [8]

### 2.3 Type of Universal Contemporary Architecture

This type is designed for dense settlement in urban area (such as in Perumnas Banyumanik area (Fig. 6)). It is closed from the environment and opened around the yard. In the beginning design, it was allocated for small families with 3-4 family members who had low salary and had simple and light constructions. Therefore, the aspects of natural ventilation efficiency have been considered. It can be seen from the interior and exterior arrangement and building elements below:

- It had 60% of building coverage (40% of floor area, 20% of developed area and 40% of yard)
- There was opening around main building and efficient cross ventilation

- The disuse of heat absorbent materials and floor was made from cement and thin board ceiling
- Each room had door and window (the opening is 30% of room area)
- Fan and Air conditioning usage were not planned because of low ceiling and materials are easy to lose cooling energy.

The fact, because of house broadening, open area was decreased and only front yard left (3 m x 2 m or 10% of yard). It made green and shadow area decrease (which had function as sun radiation filter). This condition hampered indoor air circulation, and indoor temperature is even hotter than outdoors [7].

Main specification of each model can be seen in Table 1 below:

**Table 1: Characteristics of three architectural styles in tropical-humid region**

Parameter	Type 1 : Tradition Architecture	Type 2 : Colonial Architecture	Type 3 : Contemporary Architecture
<b>Building function</b>	Residential building	Office building	Residential building
<b>Occupants activity</b>	Recitation of the Koran, trade and household activity	Office activity	Household activity
<b>Occupant density</b>	High	High	High
<b>Location</b>	Small town (village)	Urban center	Urban periphery
<b>Style</b>	Tropical-humid architecture in Javanese traditional style	Tropical-humid architecture in the Dutch/European style	Tropical-humid architecture in contemporary style
<b>Characteristic</b>	Spread (row, random, centralized, etc)	Dense	In groups
<b>Building construction</b>	<ul style="list-style-type: none"> <li>• Roof : roof tile</li> <li>• Wall/column : wood</li> <li>• Floor : cement/ground</li> <li>• Construction : one story</li> <li>• Height of ceiling: 2.5 m</li> </ul>	<ul style="list-style-type: none"> <li>• Roof : roof tile</li> <li>• Wall/column: brick/concrete</li> <li>• Floor : cement</li> <li>• Construction : 1-2 story</li> <li>• Height of ceiling: + 3.5 m</li> </ul>	<ul style="list-style-type: none"> <li>• Roof : asbestos</li> <li>• Wall/column : bataco (kind of concrete brick)</li> <li>• Floor : cement</li> <li>• Construction : one story</li> <li>• Height of ceiling: 2 m</li> </ul>
<b>Building appearance in accordance with ventilation</b>	<ul style="list-style-type: none"> <li>• Porous wall and opening (doors and windows) with carving ornament</li> <li>• Hollowed attic</li> <li>• The roofs are in piles and there are rifts between them to enable wind blows into attic</li> <li>• It has yards around building</li> </ul>	<ul style="list-style-type: none"> <li>• Walls full of openings (doors and windows)</li> <li>• High dimension doors and windows</li> <li>• Hollowed attic</li> <li>• High roof</li> <li>• There are paths around buildings</li> <li>• Very high ceiling with ventilation mesh</li> <li>• Tower function as wind catcher</li> </ul>	<ul style="list-style-type: none"> <li>• Door and windows has jalousie (ventilation mesh above it)</li> <li>• Hollowed attic</li> <li>• Overhanging roof to enable wind blows into attic</li> <li>• It has yards around buildings</li> <li>• Cross ventilation</li> </ul>
<b>Ventilation Characteristic</b>	Very open with local element/traditional construction	Very open with modern construction (concrete, glass, etc)	Open with many restrictions
<b>Equipment</b>	<ul style="list-style-type: none"> <li>• Very limited</li> <li>• Electricity fan, heater and air conditioning are not necessary</li> </ul>	<ul style="list-style-type: none"> <li>• Limited</li> <li>• Enable fan and air conditioning usage for performance but they are not efficient (because room volume is very high)</li> </ul>	Enable air conditioning usage if the building is rebuilt
<b>Conclusion</b>	Care about environment and use natural ventilation system	Care about environment and the use of natural ventilation system is changed according to current activity	Using high technology to solve ventilation problem

### 3. THE UNIQUENESS OF TROPICAL HUMID ARCHITECTURE IN INDONESIA

#### 3.1 General View of Tropical-Humid Climate

Indonesia is situated between latitude 8° of north and 13° of south, which is a tropic region in Southeast Asia and passed by equator line. It has two seasons: Dry season (April – October) and Rainy season (November – March).

- **Temperature**

The average daily temperature is 30°C along the year and the range of maximum and minimum temperature is about 9°C. In certain areas, the temperature reaches 36°C in dry season. There are two provincial capitals in Java island, Semarang (the capital of central Java province) has temperature between 23 - 33°C with humidity between 30% - 95%, and Surabaya (the capital of East Java province) has temperature between 24 - 35°C with humidity between 40% - 98%.

- **Humidity**

The relative humidity varies between 30% - 98% and the rainfall reaches 700 mm (it is measured every year by pluviometer in rainy season).

- **Air movement**

It occurs because of the influence of Asia and Australia continents, and Pacific and Hindi Ocean. Hot wind blows from Asia to Australia in April – October, when Indonesia has dry season. Conversely, wind carrying water vapour blows in November – March and causes rainy season in Indonesia. Java Island is located on south of equator line (latitude 6° of South), and wind blows from Northeast direction to Southwest in dry season and from Southeast to Northwest in rainy season.

- **Sun radiation**

Principally, the position of the sun is always above this area along the years, and radiation intensity is 11.5 hours per day. For example, in Surabaya, the intensity is about 900 - 1000 W/hm<sup>2</sup>

#### 3.2 The Concept of Indonesia Traditional Architecture

In Indonesia traditional houses style especially Javanese, roof constructions constitute dominant appearance (roof receives sun radiation for 11.5 hours per day). Usage of soft or shinning materials and overhang roof can decrease the amount of solar radiation entering into building.

Pointed roofs and openings optimizing on wall area can increase air flow acceleration to eliminate heat accumulation in rooms [9] and make it comfortable for occupants [10].

Generally, tropical-humid traditional buildings have scaffold (except in Java and Bali), therefore, airflow in room between house and ground can decrease heat in living area (Fig. 7). Besides protection aspect, it is also used to solve the problem of high humidity [8].

Traditional houses of Sumatra, Toraja, Sumbawa, for example, have specific characteristic for traditional houses in tropical-humid area to face tropical-humid climate: broad roof cover is about 2-3 fold of vertical wall, piled roof like a crown, air penetrates through roof rifts. High volume and air movements are heat insulators for occupied rooms beneath roof. Roof cover material is made from piled shingles which has low heat transmission value. Vertical wall area made of wood constitutes heat resistance material because it is protected and used as a room for arranging air movement because of its porosity. Scaffolding construction constitutes efficient natural ventilation in order to reduce room heat and humidity [4].

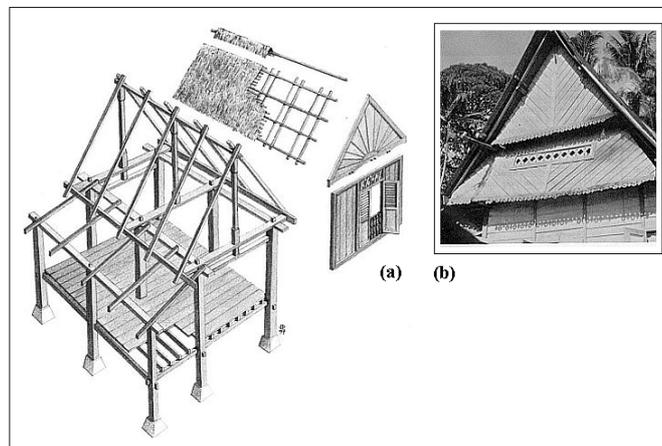


Fig. 7: Building structure in tropical-humid area: (a) scaffold, light wall and wide opening, (b) detail of attic/opening under roof [11]

### 3.3 Problems and Specific Architecture in Tropical-Humid Region

#### 3.3.1 Air circulation in room

Generally, air movement in traditional houses in tropical-humid area occurred by three ways: first, in attic room, air penetrates through roof rifts into attic [12]. Second, it flows among rooms because of high porosity wall. Third, it is formed under the house/scaffold. It can be described in Fig. 8.

The development of residential building appearance nowadays is not possible to reform traditional building only for obtaining optimal natural ventilation. On building design planning, air behaviour in contemporary houses is illustrated in Fig. 8.

- If outdoor air velocity is low, it brings about hot air movement, which flows up (out of building) through ventilation mesh (vertical movement).
- If air moves by applying cross ventilation system, it moves from opening area on wall to the other side (horizontal movement).

#### 3.3.2 Temperature, humidity and air movement in room

According to Hardiman study [12], ideal temperature condition to obtain occupants comfort in house can be described below:

- Maximum limit of comfort 27°C
- Optimal comfort 25°C
- Minimum limit of comfort 22°C

And the humidity related to that condition according to Indarto study [7] is:

- Relative humidity in comfort level is between 59 - 65%
- Relative humidity in discomfort level is between 65 - 75%

On that condition, if air velocity gets slower, occupant will feel hotter, and if the humidity rises, occupant will feel hotter also. On the contrary, if air velocity in room gets faster, the room becomes cooler for occupant. But, air velocity in rooms above 1.5 ms<sup>-1</sup> will hamper occupant comfort and activity. It is indicated by paper and ashes in ashtray flying all around the room.

Investigation result of Hardiman study on contemporary settlement in Semarang also stated that temperature in optimal comfort value above was rarely obtained naturally (without good planning).

Moreover, climate in tropical region has a small difference of temperature between day and night. Along the years, temperature is relatively constant.

Fig. 9 gives the detail of air condition in 24 hours in a contemporary house in Semarang. It is found that:

- Room used for hard activity, the temperature always above comfort level.
- Whereas for doing soft activity (in certain time), temperature on comfort level can be obtained if air movement is about 0.2 - 1.0 ms<sup>-1</sup>, but air velocity is always above comfort level.

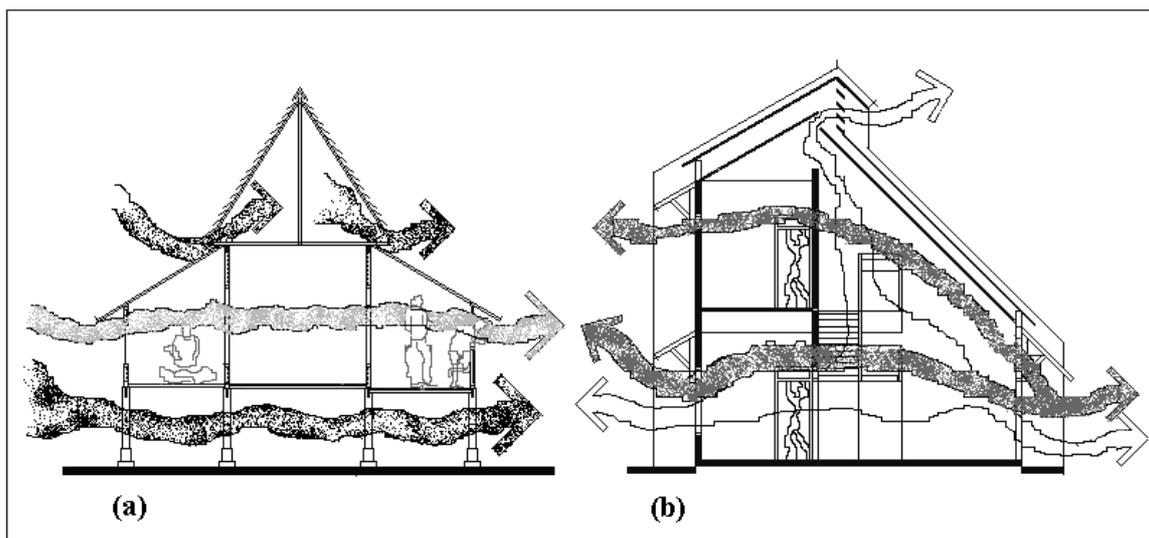


Fig. 8: (a) Air movement in traditional scaffold house [8], (b) optimal natural ventilation appearance in contemporary building [12]

Fig. 10 illustrates the temperature condition and humidity in Semarang, which related to Olgay diagram [13]. It was found that air movement along the years is needed to obtain comfort or to face high temperature and humid problems in Semarang.

Therefore, in Javanese traditional and contemporary architecture design, temperature is an important factor and cross ventilation system must be applied on it [12].

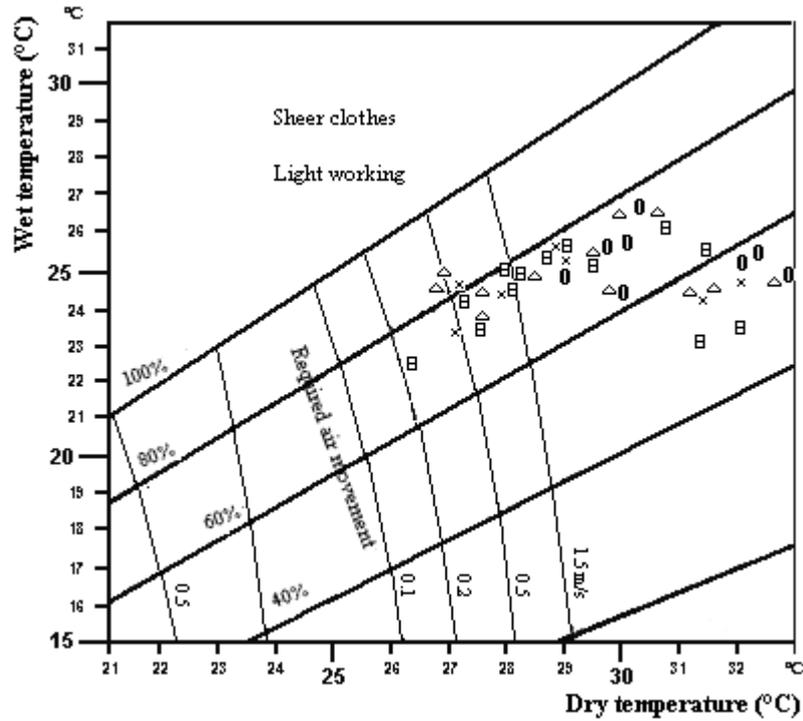


Fig. 9: Air condition in contemporary settlement in Semarang by considering air movement [12]

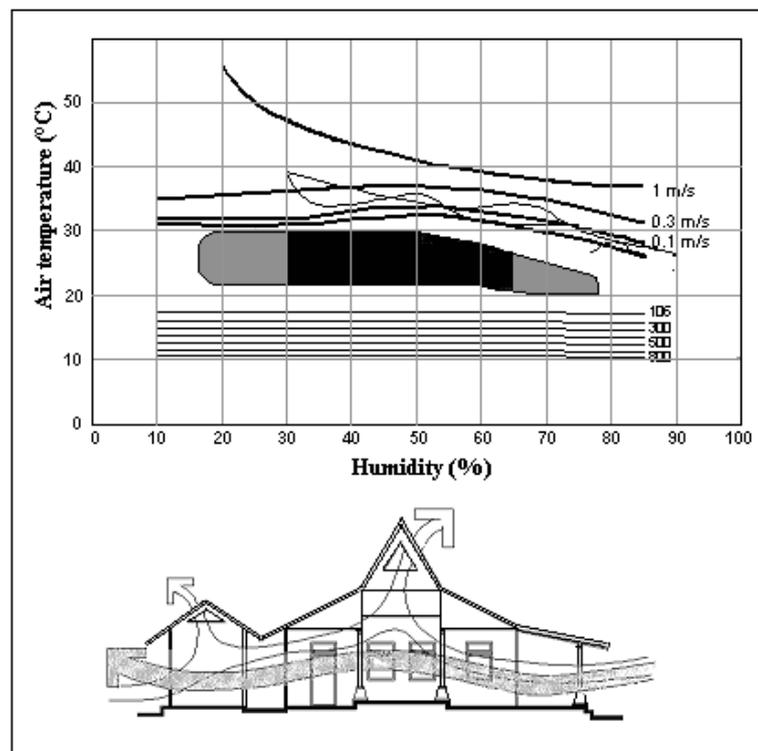


Fig. 10: Position and condition of temperature and humidity related by Olgay comfort diagram

It is very different from the case in hot-dry region, which needs humidity in building. On vernacular architectural design, we can see effort to dampen air by catching from outside and flow it through pool surface in building (Fig. 11).

#### 4. NATURAL VENTILATION CONCEPTION OF TRADITIONAL ARCHITECTURE APPEARANCE AND DESIGN IN TROPICAL – HUMID REGION

There are two analysing stages of residential architecture appearance in tropical-humid area on natural ventilation efficiency.

- Investigation of general characteristics of vernacular traditional house architecture conformed to climate parameter (sun radiation, wind, rainfall and humidity) to obtain optimal natural ventilation in tropical-humid area.
- Description of tropical-humid architecture excellence on natural ventilation efficiency. It means the response of outdoor configuration and appearance and also building architectural value (site, location, room plan, construction, technology, performance, etc) of three types of architecture in tropical-humid area on indoor and outdoor natural ventilation efficiency. These analysis have two points of view, they are building exterior construction toward other buildings and the

morphology of residential building itself (interior).

#### 4.1 General Characteristic of Architectural Appearance and Ventilation Natural in Tropical-Humid Region

##### 4.1.1 General characteristic of architectural appearance in tropical-humid region

Each region in the world (cold-dry, cold-humid, hot-dry, hot-humid climate) has different efficient pattern of climate on architectural appearance. It includes climate consideration, both seasonal climate and permanent climate, natural factors like topography, physical environment condition, vegetation, etc [15]. These microclimates still exist in every settlement [16] and are influenced by human-made environment (social, cultural includes technology progress).

This complexity has linear relationship with time constitutes continued interaction between growing design and its environment. As long as the process occurred, physical stratified adaptation is resulted. The response of traditional architecture is indicated by very slowly alteration. Conversely, contemporary architecture has various styles and respect individual freedom on their creativity. This fast alteration caused by technology progress, which forms response mechanism to control microclimate around building [4]. Therefore, natural environment and technology progress assimilate each other. But, every design must need basic comprehension of climate pattern and character.

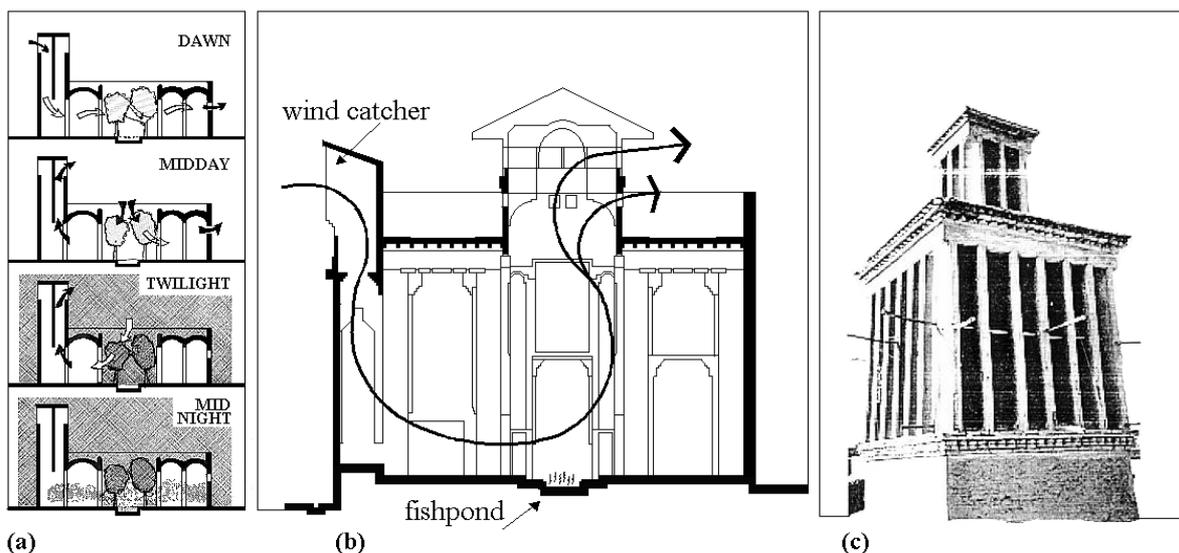


Fig. 11: (a) Daily situation schema of air movement in hot-dry region, (b) air catching in order to obtain optimal humidity in room, (c) wind tower [14]

Harmonization between building design and natural ventilation is an initial part of traditional architecture comprehension in tropical-humid region.

From architectural design point of view, those types are different. Even by using the same climate consideration, it enables the diversity of architectural morphology. There are several designs that are suitable to be applied in different climate. It is caused by universal influence.

Begun by basic character similarity on tropical architecture appearance toward the aspect of sun radiation and rain protection, natural ventilation usage is needed to ventilate and reduce indoor temperature [17]. In a special case, it needs special solution in design such as consideration in social and cultural aspects (In Indonesia, there are more than 250 cultures).

Several dominant appearance characters are discovered by traditional architecture experience in tropical-humid area in order to make a harmony to natural environment [4]:

- The best cooling principal for this region is to make an adaptation to natural environment to obtain optimal cooling in room and occupant comfort by :
  - Composing air movement to reduce air temperature.
  - Indoor and outdoor planning and vent placement for air traffic in order to eliminate heat accumulation in room.
  - Composing building form to accelerate air into building.
- Climate character that has negative influence is copious and high intensity sun radiation along the day. Endeavours to face sun radiation problems can be done in :
  - Building exterior performance planning by emphasising sun radiation protection with shadow system around building: porch in the front of the house, wall that has opening area protruded into room.
  - Roof shape and construction has function as protective performance: high volume shape (has low heat transmission value), the choice of local roof cover materials to reduce sun radiation in room.
  - The choice of colour and building cover materials (wall, roof) which complicated to absorb sun radiation, dark and light appearance of building wall.
- Rain protection is done by :
  - Using overhang on sides of building, especially above vent to tackle rainfall and

groundwater permeating and air humidity on ground surface.

- Oblique roof shape and its adaptation toward cover material to enable rain to fall directly to ground.
- Indoor temperature rise prevention can be done by:
  - Concerning winds direction (Southeast - Northwest) and suns trajectory (West - East) on building layout.
  - Opening space: simple room distribution as if a large room is easy for wind to penetrate it.
  - Air distribution in building group influenced by its porosity.
  - Indoors building element planning by emphasising cross ventilation.

#### **4.1.2 General characteristic of natural ventilation in tropical-humid region**

Air movement and natural air ventilation from exterior environment are important elements of settlement in tropical-humid area. There are several characters in order to obtain efficient natural ventilation [18] in tropical-humid region below:

- **Temperature:** It can be described as: wind that comes from part of water (lake, sea) or higher region is colder than that comes from residential area or beach.
- **Humidity:** Building sited on water boundary area will reduce room temperature if wind flows to room, especially if building faces to wind direction.
- **Energy consumption:** Houses located on slope of valley consume much cooling energy in day and night. On the other hand, houses located on top of mountain need heating energy in day and night. By using natural ventilation on building design, it is expected to solve energy consumption problem.
- **Orientation:** Building orientation has influence on health, comfort and energy consumption. Settlements in equator have roofs and wind orientation problems. Sun trajectory and wind orientation must be concerned seriously. Opening position and building orientation to North - South direction is the best solution to face winds direction and avoid direct sun radiation (in the morning and evening).
- **Land topography:** Land topography and wind altitude gradation on ground surface influence wind velocity.

## 4.2 Description of Traditional Architecture Excellence in Tropical-Humid Region

Climate efficiency, especially natural air movement, has two main points, those are: first, emphasising on urban or building environment composition and second, emphasising on building environment itself or building interior. It is difficult to make general design, both in outdoor and indoor configuration specifically to solve climate problem. Based on tropical-humid architecture analysis, we got general assumption for design reference and strategy.

### 4.2.1 Outdoor configuration of tropical-humid architecture

Building design constitutes harmonization of detail and holistic arts stem from culture. Settlements that care of environment constitute integral design. Investigation of three tropical-humid building types can be started from block plan composition (based on the analogy of Golany analysis [18]). Those are:

- **Dense form:** It can be found in old city area of Semarang in colonial architecture style. Nowadays, that area has functioned as an office region, indicating concentration on certain area, and have strong mass relation, closed and structured. In daylight, this area constitutes the centre of office activity. Energy efficiency still became a problem to support office activity. But at night, it is the opposite. This area becomes desolate and air movement influence can be felt.
- **Spread form:** This form can be found in old traditional settlement in Kudus. Spreading houses and dense occupants are characteristic of this residential area. Natural air movement efficiency in building can be felt because of building structure/construction generally made of wood to obtain natural air movement optimally. Energy consumption is very low because occupants do not use equipment which consume much energy and they have low activity (recite Koran verses, visit each other and sleep) at night to enable optimal natural airflow in house. In daylight, heat accumulation is low because people work to earn money and there are only two persons at home. It enables optimal air movement in house. Spread form buildings enable it to form spaces to catch air from outside and distribute to all building units.
- **Cluster form:** In this case, settlement in Semarang periphery area can be analysed. In this area, buildings have short distance between each other. Microclimate can be controlled and insulated from outer environment. In the beginning design of a

house: it has linear block plan composition and path pattern (air movement is not hampered), for small family (2 adults and 2 children with low activity), it has optimal room volume and opening to enable cross ventilation, and optimal natural ventilation efficiency. But, the house is developed on architectural working, which always changes according to requirement. The role of air efficiency especially natural climate is not concerned anymore.

### 4.2.2 Appearance morphology and tropical-humid architecture

#### A. Exterior aspect

- **Exterior design pattern (garden, path):** We have known the influence of building orientation toward wind direction, and other climate factors (such as shadow, sun radiation, relative humidity duration in the air). Morphology and architectural value of building environment in dynamic climate area (which wind direction and velocity always change) need a special exterior design pattern (path placement and sort of vegetation).
- **Exterior planning orientation:** Exterior planning and framer elements (character and sort of vegetation, paths and pool placement) are designed straight and parallel, to enable air movement in building. Perfunctory exterior arrangement reduces air movement in building (see design of Permumnas Banyumanik area, Emmanuel church and Kudus houses).



Fig. 12: Illustration of row building planning to obtain direct and smooth air circulation [3]

- Roof shape configuration:** Building exterior appearance can reduce and rise wind velocity in house. A case in Arab (hot-dry climate) for example, skyline generally is horizontal (formed by flat roof and has 2-3 stories). It provides strong air movement in city without restriction. Air catcher tower and pond in house area are needed to obtain comfort temperature and humidity (see Arabic houses in Fig. 11) [14]. In tropical-humid architecture, pointed roofs reduce air velocity in building, but inside, air velocity conformed to air dynamic and opening area. Roof angle is effective to solve climate problems (rainfall, roof cover, and air velocity) by using 45° of angle [19].
- The role and composition of exterior opening:** Small open space and bend path constitute air movement restriction in tropical-humid region. It is proposed to have large open space dimension and vegetation to provide shadow area and optimal air movement (see design of Kudus houses and planting pattern). Smooth natural ventilation in building can be obtained because of vegetation absorbs sun radiation. Grass, paving and damp ground can reduce sun radiation so it causes air to become cooler.
- Vegetation:** Besides vegetation function above, it also absorbs dust and air pollutant and reduces noise. Kind and density of vegetation influence heat efficiency in building. Ground covered by grass and bush absorb dust from air. Besides providing comfort for occupants by natural ventilation, vegetation also beautifies settlement environment.
- Social interaction and culture:** settlement that provides open spaces for vegetation, tree and pool to do social and culture activity. It provides interaction place for occupants and creates green space.

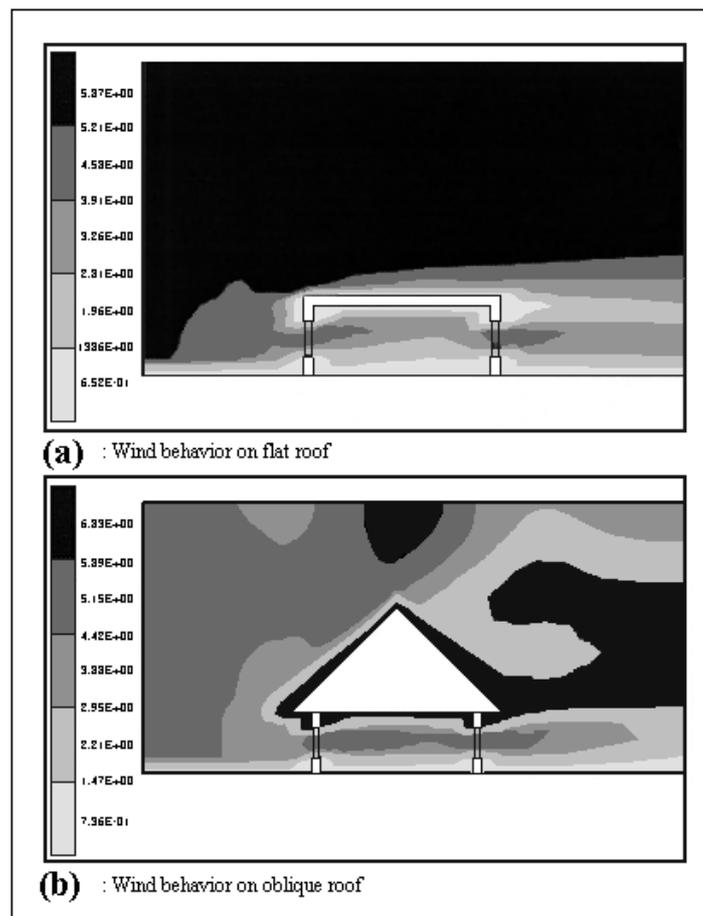


Fig. 13: Illustration that shows comparison of building roof shape (a) High wind velocity on flat roof surface and (b) obtained optimal wind velocity by using pointed roof [19]

**B. Interior aspect**

Building interior physical factor, haphazard building development, dense occupant with high activities and electricity equipment usage provide heat accumulation zone in building and evoke natural ventilation does not work [7]. In this discussion, we find a description of natural ventilation efficiency in three types of houses in tropical-humid area.

- **Room organisation toward air contact:** Each building has microclimate. In tropical-humid area, cool air neutralizes building temperature. Haphazard room arrangement causes natural ventilation does not work. Bedroom and living room must be sited on

building flank. Bathroom and kitchen need air circulation to waste odorous air and reduce humidity. It is also good to site on building flank.

- **Alley function and linear room organization:** Linear room and vent placement on wind direction provide cross ventilation and this air movement can penetrate hot air in room [20].
- **Room interaction that has different function:** Previous discussions have not investigated about the difference of room function in detail because it related to the sort and intensity of occupant activity. It includes integrated and separated room efficiency.

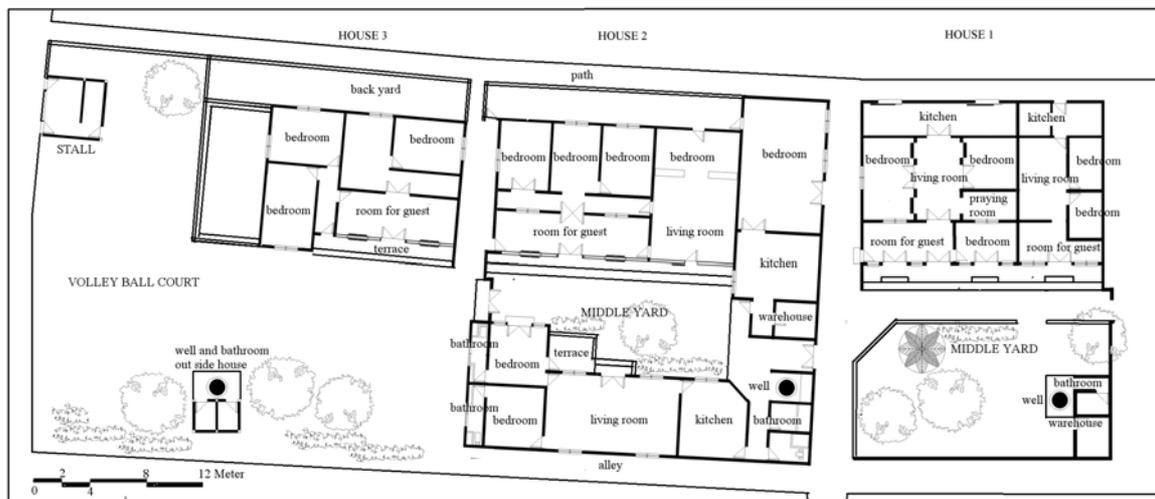


Fig. 14: Situation of air contacted room’s placement and opening placement in each house [3]

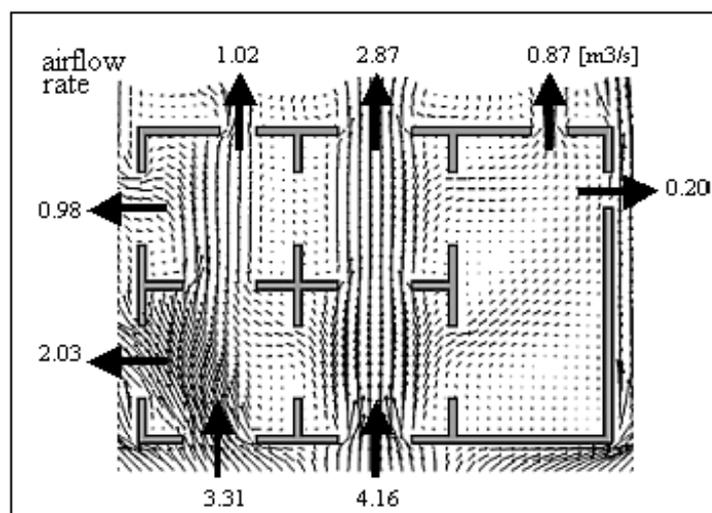


Fig. 15: The result of air circulation simulation on linear room composition, illustrates continuous air movement and cross ventilation on room opening [20]

- It needs a distance. Bedroom, kitchen must have distance to avoid odour or polluted air.
- The same function. It needs to unify room that has the same function both for occupant activity and electricity equipment like TV, sewing machine, etc. It is related to energy consumption in each room.
- Air pollution. It needs to consider room site toward wind direction that brings dust, smoke and noise.
- **Electricity equipment usage:** For special rooms (bedroom and studio), it is suggested to avoid an arrangement that causes heat accumulation excessively. In that room, opening must be designed optimally.
- **Local material building:** In tropical-humid settlement cases, local building material and natural element efficiency are needed to harmonize environment and natural ventilation. Porous wall (made of wood/plaited bamboo or grating cement wall), opening (door, window) and exterior Venetian blind that made of glass are specific part of tropical-humid architecture.
- **Social interaction and culture:** It has an important role in indoor organization, because it is related to natural ventilation. In village settlement (in Kudus), veranda has a function as living room as a room to make social interaction with society and it does not consume much energy. It is sited in the front of the house, the usage intensity and occupant

activity in this room are high. It needs optimal natural ventilation. This concept was adapted by contemporary houses in urban area by creating living room in house buildings. High volume room is the best solution to solve tropical-humid problem. In special design, patio or vide are used to connect first and second floor in urban house buildings.

## 5. CONCLUSION

- The main point of house building design is to provide comfort for occupants to do their activity at home by considering macro and microclimate.
- Natural ventilation influence can solve air pollution in house if it is applied correctly like in traditional architecture in tropical-humid area.
- Various traditional architecture in the same geographical area (like a description of various traditional architecture in Indonesia) indicates direct relationship between form, climate (especially natural air movement) and cultural aspects. Rapoport [21] stated two factors of settlement framer are cultural and modifying factors, like: climate, construction, building material and technology.

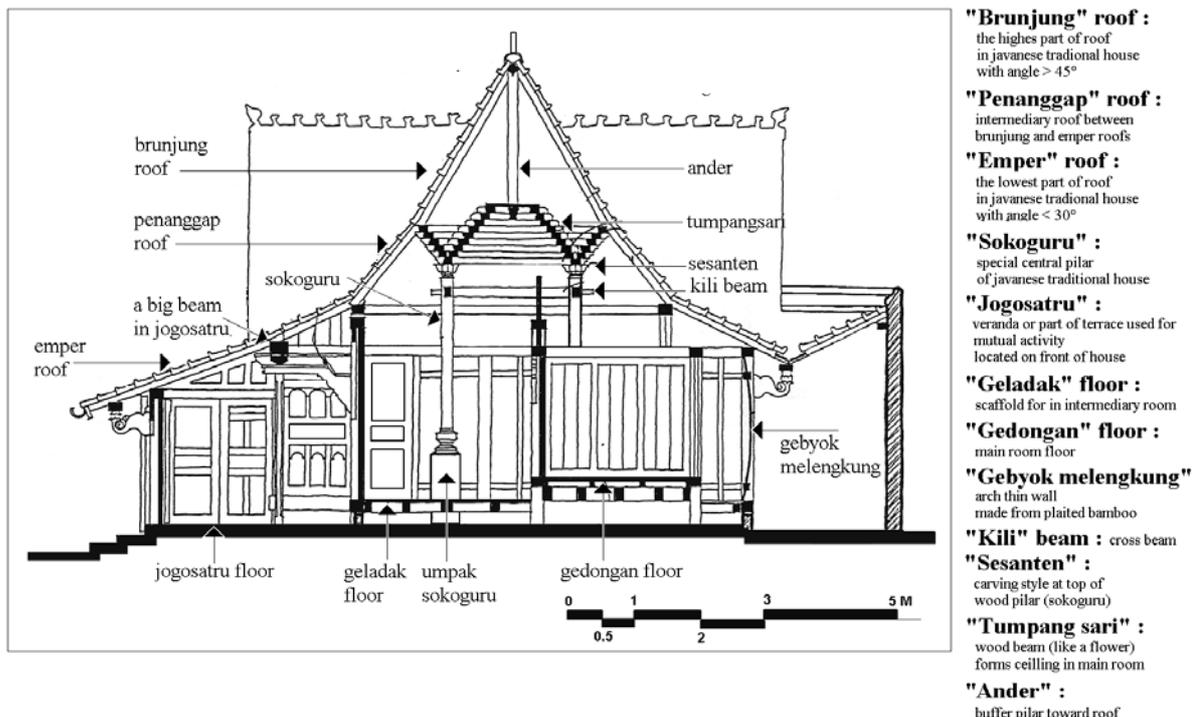


Fig. 16: Indoor construction which shows building materials, floor height position and room volume in order to obtain optimal air movement [3]

- Traditional architecture concept in tropical-humid area has strong relation with climate.
- Building orientation, has strong correlation with wind direction and sun radiation
- Roof shape and construction has direct influence on building temperature. It also has a little influence on eliminating heat accumulation by providing optimal air movement in building.
- Architectural style has stronger correlation with construction and technology than climate.
- Development indicates critical changing if we try to perform traditional architecture style. Transition process occurs very fast without natural environment adaptation. Current development tends to response technology progress to support building development needs.
- Architectural creativity is still supported by natural ventilation, as a main problem of buildings in tropical-humid area.

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