HOW A BALINESE TRADITIONAL HOME CREATES A COMFORTABLE INTERNAL ENVIRONMENT WITHOUT RESORTING TO ENERGY USAGE

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Abstract

Balinese traditional home is one of traditional architectures in Indonesia in which it still survives up to now. The home as a part of Balinese Traditional Architecture derives from Balinese Hindu belief and their custom which have a lot of Hindu philosophy. Base on this philosophy, the house which is created as a model of human being and a model divine of macro cosmos. The aim of this is to create harmony between micro cosmos (human being) and macro cosmos (nature). Physically, the usage of body measurements in the whole building dimensions has approved of how the implementation of a model of human being is created. Another thing is of how to abstractly create the building to have a soul through using basic dimension, mantra, and ritual for permission to the holy and devil spirit. Because of this, the building becomes a really unique thing.

However, an interesting question reveals in relation to green building i.e. how does a Balinese traditional home create a comfortable internal environment without resorting energy usage? The presented paper has addressed it which is approached from the building layout to the building components. From those, the home appears that it has fully accounted to respond a warm-humid zone of the tropical climate. And a comfortable internal environment can be reached maximally through the use of open air concept or courtyard pattern in the building composition, most open and small buildings, the use of non bearing wall and also the critical point is the use of natural materials with low heat storage and large air cavity. Therefore, this means that the Balinese home has performed itself as a green building.

Key words: Balinese Traditional Home Comfortable Internal Environment

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1. Introduction

Bali constitutes a small island located between Java and Lombok Island, separated by the Lombok and Bali Strait. Although, it is separated by the strait, Bali and Java has a very close relationship since ancient ago. Many Monks or Priests from Java came and stayed in Bali in order to socialize Hindu Religion and to enhance social life of Balinese. It is predicted to take place in the early eight century. In line with development of Hindu in Bali, Balinese architecture was predictably born at this century. This is due to the establishment of Balinese architecture has contained a lot of Hindu philosophy. The golden age of Balinese architecture took place when Bali was under the rule of of Majapahit Dynasty based in East Java. The Majapahit era occurred from 1400 to 1600 century. After this era, the Dutch then colonized most areas of Indonesia including Bali. Their culture also gave new values in indigenous architecture particularly Balinese architecture.[1]

From the historic time, culture exchange among indigenous people and people who came to Bali had colored Balinese culture, also leading to the Balinese architecture values. It can be seen from its patterns of settlement, building form and materials, to decorative elements. A cross pattern or *Catus Patha* is a pattern of settlement which is very dominant to be used in most areas. The pattern is the mayor concept of settlement in the era of Majapahit Dynasty, while linier pattern was very familiar before the era. This cross pattern derives from Hindu philosophy of *Rwa Bhinneda* meaning that the opposite values as a part of nature role, such as father-mother, top-down, North-South, East-West, good-bad, left-right, and others. Meanwhile, the linier pattern which is still exist in several old villages such as Tenganan, Bugbug, Taro, Wongaya Gede, Julah, Sembiran, Bayung Gede, and etc. The concept of this pattern is very simple

1 Dinas Pekerjaan Umum Daerah.1984. ***Rumusan Arsitektur Bali***. Denpasar: Pemerintah Propinsi Tingkat I Bali.

to which the area is divided into three zones or what is called ***Tri*** *Mandala*, consisting of pure, neutral, and impure zone.

However, Balinese traditional home usually uses nine zones, called with *Sanga Mandala* which is principally similar to *Catus Patha* pattern. The well known pattern in Bali is called with *Natah* meaning that an open space in the middle or in the center, as a similar pattern to compound or courtyard pattern. The number of pavilions on the site is oriented to the center which is open space. From this concept, the Balinese really enable to move actively for supporting their home activities. The width of the site is at least approximately 400 m^2. The distance and dimension of the pavilions use owner's body metric. All of these are implementation from Balinese belief symbolizing that the home is a model of human being as micro cosmos and a divine model of nature or macro cosmos. To make harmonious relationship between micro and macro cosmos is one of the aims from the Balinese. To make harmony and respect to the nature, the Balinese underline their life into three important points; philosophy, ethics, and ritual. Those points are also applied to create their house or home. These prevail in the whole process of building development including in terms of material selections.

The Balinese traditional home just uses rectangular forms with small dimension. And the building structure used in the whole pavilions is skeleton structure. The structure is honestly expressed without disguised, while the building's wall is just a non bearing structure. The main building structure uses selected wooden materials according to the hierarchy of timber. For instance, Jackfruit and teak wood are the high hierarchy of timber used to human buildings, but yellow *champaca* wood is commonly used for shrine places or temple buildings. Besides that, roof covering material between human and temple building is also differed according to their ethics; *alang-alang* grass material for human building and palm sheet for temple building. The use of palm sheet for human building is unusual

and out of ethics. The form of roof is hipped and pitched with certain angle between 35 -45 degree making one of clear identities from Balinese traditional buildings. While fence wall is traditionally made of *paras* stone, using clay as plaster, no concrete or reinforced concrete, and no Portland Cement (PC). And also its floor uses only compacted soil without coated by other material. This has approved that the material usage of the building is a 100% natural.

Nowadays, most Balinese have faced big problem in the use of timber based on the hierarchy, since lack of the timber's availability and possible weaknesses of keeping the truth of the rule and tradition. They then have begun to use it following market availability, though it does not follow the regulation. They possibly need materials which are more strong, healthy, modern, and aesthetic even durable. But the use of kind materials for excluding the main structure are not regulated into the role, so they can select freely the materials for it. In addition, many options of building material which are availability in the market have encouraged them to use artificial materials. The change of building material usage from natural to artificial in several parts has undoubtedly shifted indoor climate in every hour per day. The use of solid material with less air cavity such as ceramics, cement plaster, reinforced concrete, teak wood ceiling, and other especially at wall, floor, and roof has raised indoor temperature to be hotter than usual.

What we are going to do in this paper is to address of how smart a Balinese traditional home to create comfortable internal environment without resorting to energy usage. Another word is of how the home properly responds the climate into passive systems, so the internal comfort can be achieved. The main approach to address to the building home is from climate zone in which Bali regions is located in the warmed-humid zone. From this point, the home will be analyzed. And physically, the building of home which will be addressed in this case is in the

original and traditional role by using a 100% natural material.

2. Factors Affecting Comfortable Internal Environment

There are some factors affecting comfortable internal environment, those are climate, site, building, and human factor.

2.1 Climate

Climate is the most important factor to affect outdoor and indoor comfort, and the first step to consider energy efficiency into building design. Climate and energy efficiency has closed relation, meaning that efficient energy will be reached if the building fully responds the climate, or by designing a climate responsive building. The significant impact of the building is micro climate, however, micro climate really depends on meso climate and meso climate is affected by macro climate. The climate relates to solar heat or solar radiation, temperature, wind flows, rainfall, humidity, and topography. In the climate issue, temperature is the most important thing to be considered, this is because temperature mostly refers to comfort which is influenced by other climate factors such as solar heat, wind flow, rainfall, humidity, and topography.

2.2 Site

As mentioned above, temperature on the site is really influenced by micro climate, and in turn, microclimate is mainly dependent upon many factors such as site surroundings, geology, topography, soil covering, vegetation, and other natural elements. These factors, at the end, can influence thermal outdoor and indoor comfort. There are many things to consider in site surroundings such as; site orientation, building density, soft and hard landscaping elements around the site, as well as the number of vehicle or traffic. Geology and topography of the site also can make a difference of micro climate, for instance; sandy or all soil structure with limestone or gravel will make different temperature on the site. Site with flat, less, and sharp slope

especially to the East or West will make different temperature of the sites. All of those relate to the site in absorbing and collecting solar heat. Heat absorption on the site easily takes place due to soil covering, kinds of vegetation, and other landscaping elements.[2]

2.3 Building

Buildings on the site can be said as a part of hard landscaping elements. At Inside, there are a group of spaces, enabling every space has different internal comfort. This really depends on its position from building perimeter, space volume, material usage, and number of window. Meanwhile, some indicators making buildings to be comfortable internal environment are building orientation, form, shape and volume, structure and materials, as well as building devices. Orientation is an essential consideration to design an environmental building. As Norman Foster said that a variety of elements that influence architecture to be green are social forces, technology, orientation, movement, context, and ecology. And he then clarifies into illustration of a pyramid. At the top are the sophisticated and expensive active systems, such as photovoltaic panels. In the middle tier are passive systems; while at the bottom of the pyramid is orientation: how the building sits on the site and interacts with its surroundings.[3] A concept of Building orientation between Asian and European architecture is clearly different. Asian architecture is to avoid direct sun light, while European architecture needs building orientation to the South as sun collector. Though, the similar result of this strategy is that the South is the best orientation of the building, but the reason is clearly different. While the maximum of building width in the way of passive systems is 12 meters, due to for getting daylight from both building perimeter

2 http://booklens.com/kevin-lynch/site-planning

3 http://www.architectureweek.com/2000/1011/news_3-1.html

is only 6 meters so both sides are 12 meters.[4]

2.4 Human Factor

In relation to internal comfort, human factors involve number of users, kinds of activity, work product, as well as norm and culture. The more users inside of the building the less comfort to be felt for each. This is due to metabolism factor in which the heat gains going in to the body is much more than heat losses, so that the humans become too hot. Muscular activity produces large amounts of heat, even when totally at rest the body still produces amounts of heat. This is known as the basal metabolic rate. Body conditions become comfort when there is a balance between heat input to the body and heat loss from the body. The human body is only comfortable when we have a constant body core temperature of 37.5^{o}C and a skin temperature between 31 and 34^{o}C.[5]

3. General Conditions of Bali

This will address the conditions of Bali particularly physical conditions such as geography, topography, geology and climate in order to give general information behind an issue of the internal comfort of the Balinese traditional home.

3.1 Geography

Geographically, Bali is located between latitude 8°03'40" and 8°50'48" South and longitude 114° 25'53" and 115°42'40" East. It has land area of 5,632.86 km^2 or 0.29% of the total areas of Indonesia and coastline length -of approximately 430 km.[6]

3.2 Topography

4 Nicholls, Richard. 1997. *Low Energy Design.* Huddersfield: Information Booklet

5 *Ibid.*

6 Pemerintah Daerah Propinsi Daerah Tingkat I Bali. 1997. *Rencana Tata Ruang Wilayah Propinsi Dati I Bali Tahun 2010.*

From topography sight, a West- to- East volcanic chain in the middle divides the island into half, leading to different condition between the Northern and Southern Bali. Volcanic Mountains occupy the island's hinterland sloping steeply to the sea in the north, while in the south the slopes are more gradual. Bukit Peninsula at the southern area is the southernmost extremity of Bali Island which is characterized by a small mountain chain runs from East to West.

3.3 Geology

The mainland of Bali is generally formed by alluvial deposits which consist of limestone, sand, and gravel. Most parts of uplifted coral reefs are located at the Bukit Peninsula, the southern part of Bali. The hills in this peninsula are up to 200 meters above sea level.[7]

3.4 Climate

Bali region has tropical climate with two seasons; rainy and dry season. Rainy or wet season usually occurs in October-March, and dry season is from April to September. The season is influenced by the monsoons which commonly blow from Southwest or West and from Southeast or East. The highest intensity of solar radiation is up to 502W/m2 and the temperature is up to 33^{o}C. The average rainfall is approximately 197 mm/ year and the highest is 453 mm. While the average wind velocity does not exceed 12 knots, and the average relative humidity is between 70-86% per month.[8]

Since Bali is located near the Equator, it means that daylight hours are consistently 12 hours**.** The variation in daylight hours throughout the year is very slight. The shortest day occurs in late June, whilst the longest day is in late December. The difference

7 *Ibid.*

8 Bali Government Tourism Office. 2010. *Bali Tourism Statistic 2010.*

between the two is just an hour. From mentioned above, the primary concerns of the tropical climate in the warm humid region are high temperature and humidity. So it will need several strategies to prevent negative impacts, and to take full benefits from the climate's positive impacts.

4. Design Strategies as Criteria for the Warm-Humid Zone of Bali

The zones characterized by high rainfall and high humidity have minimal temperature differences during the day and throughout the year. And the solar radiation is very strong to raise temperature on the earth surface. To prevent negative impacts of this zone is of how to protect the building from direct solar radiation. Other thing is of how to avoid direct air circulation as the air contains amount of vapor making unhealthy. To solve the impacts into building design, it is required design strategies as criteria. The following design strategies are.[9]

4.1 The main strategies:

- Provide maximum ventilation and free air movement by large openings;
- Provide maximum shading of direct and diffuse solar radiation;
- Avoid heat storage;
- Use reflective outer surface;
- Use ventilated double roof;
- Use vegetation to moderate the solar impact.

4.2 The Settlement Planning Strategies:

- Topographical location with maximum air velocity and shade;
- Orientation to minimize sun radiation impact;
- Orientation to maximize natural ventilation by winds;

9 Gut, Paul. 1993. *Climate Responsive Building*. Switzerland: SKAT, Swiss Centre for Development Cooperation in Technology and Management.

- Scattered pattern of buildings;
- Hazards, mainly floods and storms to be considered.

4.3 Building Design Strategies:

- The main elevation and rooms should be placed facing north and south and towards the prevailing wind;
- The form should be spread out;
- Provide generous shade for direct and diffused radiation;
- Provide effective cross ventilation.

4.4 Building Component Strategies

- Heat storage and time lag should be minimal;
- Thermal insulation is not effective except on surface exposed to direct solar radiation;
- Materials should be permeable to air provide protection from precipitation;
- Reflectivity and emissivity are important.

5. ANALYSYS OF A BALINESE TRADITIONAL HOME TO CREATE COMFORTABLE INTERNAL ENVIRONMENT

The analysis will be started from the building layout to the building components.

5.1 The Building Layout

The walled compound with a specific entrance gate is one of the Balinese home identities. With more than 1.5m high, this fence protects the exterior from unpleasant factors from outside. One of those is to avoid direct wind due to containing great amount of vapor, but the fence material is made from with natural stone of ***paras*** plastered by clay so that the air can go inside through the fence without great amount of vapor. The wind direction above the fence can be captured and directed to the exterior and interior. This is to utilize indirect wind for internal environment (*See figure 1*).

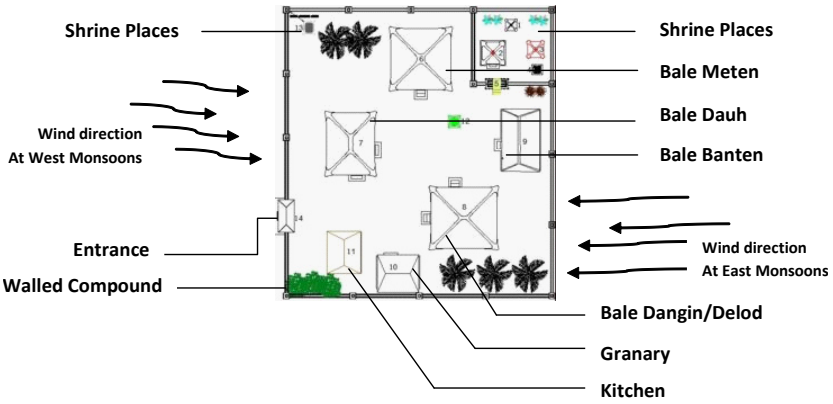

Figure 1: ***Wing flow from opposite*** **direction**

5.2 The Building Composition

The home consists of a group of pavilion which is composed into a compound pattern and is well known with ***Natah.*** Other name of this pattern is an open air concept or a courtyard pattern.[10] There are separated six pavilions with large and free spaces between them, so this allows airflow providing natural ventilation for cooling and a better hygienic environment. The surface is only soil and other cases are covered by grass which is very low heat storage capacity and is easy to release to atmosphere at night. The building for kitchen as the source of heat is located at south-west to which the location is the most appropriate for it. This is because dominant wind direction every year comes from southeast or east and northwest or west, so heat radiant from kitchen's activities does not move to the other buildings (*See figure 2*).

10 Budiharjo, Eko.1995. *Architecture Conservation in Bali.* Yogyakarta: Gadjah Mada University Press.

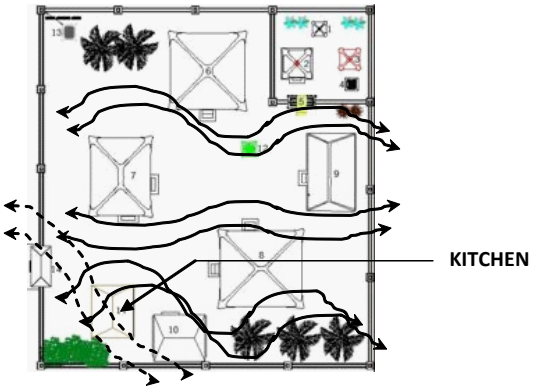

Figure 2: Freely airflow through buildings from East-West and Southwest-Southeast

5.3 The Building Orientation

Orientation is the basis of building composition in the Balinese traditional architecture. Every building has own orientation and position on the site. Since the orientation of all building is to the center as open space or *Natah*, each building has most different orientation, as *shown in figure 3*. Even though a critical point of the building in this climate is the east and west elevation due to low sun, there are two pavilions in the home facing to the east and west the critical point, i.e. *Bale Dauh* pavilion faces to the east whereas *Bale Dangin* to the west. The two pavilions, however, have their protection from solar radiation by the placement of massive wall at one side, and other side is expected to get shading from another pavilion or from the placement of vegetation as a canopy effect.

5.4 The Building Shape and Form

The most Balinese building characters are open, small, rectangle and low rise building. Each pavilion in one unit of the home has not more than 6.50 m width meaning that there is good response from the climate. Since this dimension is very easy to get natural daylight from all sides including natural ventilation. The low rise building is also very good to minimize solar radiation. This favors ventilation and heat emission at nighttime. Moreover, cross ventilation at afternoon or nighttime

easily occurs since most of them are open buildings (*See figure* 4).

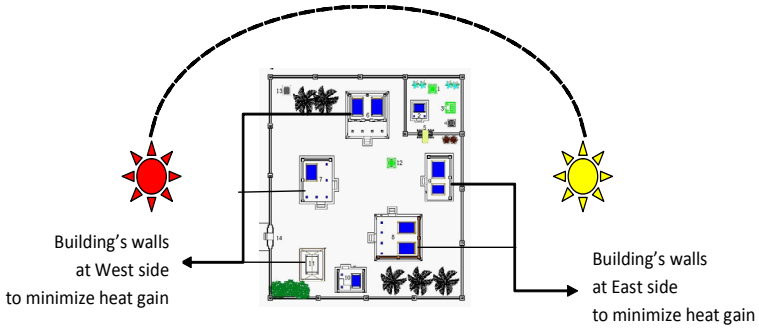

Figure 3: The positions of building wall to protect indoor comfort from solar heat

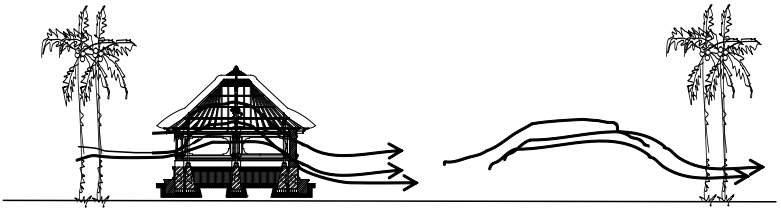

Figure 4: Cross ventilation at night and mid day easily occurs

5.5 The Building Components

The foundation and floor of the pavilions are constructed by natural stone and compacted soil as building floor. Those materials have low heat storage and good absorption especially from rain water. With at least 0.8 meter high from the soil surface, the floor can sufficiently avoid rain water, supported by wide overhang. If the foundation absorbs rain water on the surface and keep it, cold air inside will be exit at hot temperature in the afternoon, so that it helps internal comfort. This is a part of evaporation system. In the contrary, the floor will keep solar heat entering the building and then will naturally release it at night when the means temperature is drop, so that the room becomes warm when sleeping (*See figure 5).*

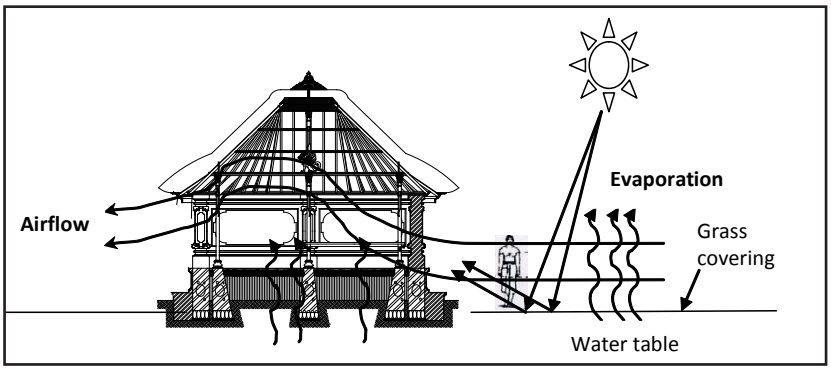

Figure 5: Creating comfortable Internal Environment

The enclosed building of the Balinese home is only one; called *Bale Meten* or *Bale Daja* is located at north side facing to the south. The essential function of this pavilion is for childbirth, feeding a baby, and women ritual ceremonies. Because of its function, the pavilion is rounded by wall equipped by enough windows in front and at back. These aims are for getting natural daylight. While others are open buildings in which the placement of wall is only one or two sides. All pavilion walls are non bearing structure, so there is a space between wall and building overhang which is good for getting air circulation, or catching indirect wind. In addition, the wall is made as similar to the fence with sufficient air cavity as breathing wall. Therefore, the function of the wall is only for protecting the user from negative climate impacts and hazards.

The main structure uses skeleton structure which is honestly expressed without using ceiling. While the roof uses pitched and hipped forms. This gives a wider volume of the pavilion and helps to give a psychological comfort for the users. The main structure materials use timber for columns and beams including the main roof construction supported by trusses of bamboo. As known, these natural materials are one of the lowest heat storage and heat radiant, so it can be said as the best materials for creating comfortable internal environment. What is about

the material of roof covering as a critical part of the building to receive solar heat? The Balinese creates roof covering by using *alang-alang* (thatch) grass for their homes and palm sheet for their shrine places. This material is also very good to respond warm-humid climate. With large air cavity and the low heat storage, it enables to create internal comfort well.

6. Conclusion

From mentioned above, the following points can be summarized, such as:

- The Balinese traditional home is one product of Balinese traditional architectures which use a lot of Hindu philosophies behind its physical performance. The nine zones or *Sanga Mandala* is the basic concept to compose the building's function according to its hierarchy.
- *Natah* is the familiar name of building composition in which all buildings on the site is composed and oriented to the center as open space, so it can be said as an open air concept or courtyard /a variant of compound patterns. In fact, this composition is mostly fit against the tropical climate of the warm-humid zone, as wind circulation can freely flow through and between the pavilion
- An identity of the Balinese traditional home is characterized by walled compound with entrance gate. All pavilions inside of walled compound are composed to follow their role and hierarchy, so it clearly forms an open space as called Natah. The wall height is more than 1.5meter to secure their home activities from outside and to avoid direct wind.
- And all dimensions use body measurements to govern proportions, deriving from the home owner. This is a part of symbols to create a model of human being and a divine model of nature or macro cosmos. The aim is to create a harmony between the home and environment.
- Although the home consists of several simple pavilions, it

has performed a clear concept to respond the climate. The pavilions are small, open, rectangle, low rise buildings which fulfill building form and shape requirements in the warm-humid zone. In addition, it is also supported by the roof's form using pitched and hipped roof with ceiling, so that it makes a bigger volume of space and a better indoor airflow.

- Since the pavilions use a 100% of natural materials with the lowest of heat storage and heat radiant, as well as large air cavity, such as compacted soil for floor, timber as the main building structure, clay for wall plaster, and *alang-alang* grass for roof covering as a critical point at tropical climate, the buildings, then, can create naturally a comfortable internal environment. This natural system, certainly, is without resorting to energy usage in its building operation.
- From this point, we can learn a lot of how the smartness of the traditional architecture to create indoor and outdoor comfort in the way of energy efficiency as the essential need for the present and future generation.

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