

Implementing bamboo research into holistic architecture design for creating thermally comfortable interior environment in Gili Meno, Indonesia

Octaviana Sylvia Caroline

Interior Design Department, School of Design, Bina Nusantara University,
Jakarta, Indonesia 11480

Corresponding email: baby@binus.ac.id

Abstract. Gili Meno is located on Northwest coast of Lombok, Indonesia. Surrounded by crystal water and microclimate tropical weather. Nowadays, modern materials for building in Gili become choices due to the access from suppliers from the big islands surroundings. The use of indigenous materials such as bamboo become rare for wall, ceiling and roof. However, bamboo is a promising choice for cooling down the interior thermal of the building and considered as a sustainable building material. The project is designed as a sustainable architecture for boutique villa that aims to attract tourist by its concept of holistic design and to embrace bamboo as indigenous local material for sustainable holistic design. This journal focused on bamboo for wall, ceiling, roof and shading as design elements to create thermally comfortable interior of the villa. It uses a research by method of implementing research bamboo that has been done by other researchers and site observation, observing the type of bamboo and designing the holistic architecture. The research found that the use of bamboo with holistic approach for the wall, ceiling, roof and shading with the understanding of the nature will be promising with further research needed to create thermally comfortable interior environment.

Keywords : Bamboo, sustainable holistic design, sustainable building material, thermally comfortable interior environment, sustainable architecture, indigenous material, Gili Meno

1. Introduction

Characteristics of bamboo : fast growing, quick maturity, high productivity, and high strength, and also considering inexpensive and permanently available have been made bamboo receiving consideration attention as a sustainable material.[1]

The project was designed as a sustainable architecture for boutique villa complex that aims to attract tourist by its concept of holistic design approach and to embrace bamboo as an indigenous local material for sustainable holistic design. However this journal is focused on bamboo as a sustainable indigenous building material for wall, roof, ceiling and shading to creating thermally comfortable interior environment of the villa as part of holistic design of the whole complex. The research design is focused to use bamboo culm as wall, roof, ceiling and shading with some modification to meet the function and sympodial bamboo as a 'living' shading.



Nowadays , modern materials for building element in Gili become choices due to the easiest access from the suppliers that are plenty to find in big islands near Gili, such as Bali and Lombok. The use of local indigenous material such as bamboo becomes a rare choice for wall, ceiling and roof.

The site of this project is in Gili Meno, a tiny island in Indonesia. The island is on Northwest coast of Lombok, Indonesia. It is one of the smallest of the three Gili islands in West Nusa Tenggara. Surrounded by beautiful crystal clear water and a warm, tropical microclimate with a dry and wet season throughout the year. Usually, dry season lasts from May until October and monsoon starting in November and continuing through to April. The temperatures range between 25 °C to 34 °C, with an average annual temperature of around 29 to 30 °C. Shadowing by two major mountains within distance , Mount Agung on the West and mount Rinjani on the East.

The project research started on mid of 2017 , followed by designing and preparing the site and the bamboo for main material. Preparing the site has been started since December 2017. Preparing the Bamboo material has been started since February 2018 .After preparing the site, the construction of the villa will be divided into 2 phases, first phase is the construction of one-level villa and of the second phase is the construction of two-level villa. The two phases will be started on August 2018.

2. Methodology and Research Design

As world toward to sustainable design, architects play key role and have a responsibility to minimize the use of energy. They have to design buildings that use less energy in the design, construction, and operational phases as well [2].

The research method of this project is a combination of literature reviews by other researcher with the same interest, complete observation of site, observation of bamboo type and implementation and design the holistic architecture. Sustainability assessment criterias are defined through literature review, field observations and interviews with three stakeholder[3]. Through applying research studies into practice, designers become a change agent in creating a better world [4].

Implementing research into the holistic design process, integrated design process involves all related part into a project and becomes very important as the trend in the industry is moving toward sustainable buildings [4] from site analysis , landscape, architecture , interior, structure and maintenance.

Implementing research into design becomes very important to fill the gap between theory and practice. Research has shown that although designers' knowledge of Environmentally Sustainable Interior Design (ESID) and interest in embracing it has grown, this has not necessarily to always translate into action, particularly where materials selection is concerned so there remains a gap between theory and practice coined 'the sustainability gap'[5]. Incorporating research into the practice is best seen in a holistic design approach, especially for sustainable designers. To implement change, designers must embrace research and become an advocate for design research [4].

The design of the wall, ceiling, roof and shading as part of holistic design started by implementing the research of bamboo as material in many vernacular design in Indonesia, Vernacular practices have minimal impact on environment [6] ,based on local knowledge. A product of the indigenous people that is constantly maintained and held in life, which although is local, the values contained therein are considered universal [7] and analyzing the

position of site and the nature surrounding, designing the site plan, landscaping and the orientation of the villas and designing the architecture of the two types of the villas.

3. Thermal Comfort Approach for Design

Thermal environment is an important element in interior to be thought by an architect and to be created as a result of the holistic design. We spend more than 90% of our life indoors so it is important that designers and engineers need to take into account a range of factors such as sick building syndrome, thermal, visual and acoustic comfort [8]. The individual thermal sensation is mainly connected with the thermal balance of the human body and depend on four environmental parameters (air temperature, humidity and velocity, and internal envelope mean radiant temperature) and two variables connected with the human being (physical activity and clothing) [9]. Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied models (PMV-PPD) defined as the difference between the internal heat production and the heat loss to the actual environment.

The use of indigenous materials such as timber, bamboo, and sago palm leaves increases the effectiveness of the passive structural design and ventilation openings since the indigenous materials are known to have low thermal mass [9] and expected to decrease the thermal inside the building.

Contact with natural environments promotes psychological restoration and reduced stress and anxiety[11] further research needed if this is apply for the use of natural material in its genuine form for example bamboo culm.

The ventilation in the indoor space in tropical regions was maintained high with wide building openings (windows and doors) facing the predominant wind direction[10] and the glass window facing north and south of the building.

Radiant temperature is strongly conditioned by the envelope characteristics[9].Roof as the top surface of the building will get direct sun the most than other element in the building so it will be important to consider the material of the roof as important element that plays the role of creating comfortable thermal interior. The surface temperatures of roof and walls are analyzed to understand the influence of air cavity and thermal mass of the structure[12] while considering the indigenous material for wall in certain position, especially in tropical weather with consideration of the sun path , is an important decision in sustainable architecture design.

Roof is the important part that has to be considered to create thermally comfortable interior environment. Researches were undertaken for evolving a cool roof technology to reduce the cooling load thereby, researched the performance of various organic 'phase change materials' and increased the roof reflectance cooling energy savings [13].

Shading, thermal insulation, building orientation and glazing are a few heat prevention/reduction strategies, incorporating passive architecture like insulating roof and walls, adding shading devices to windows and orienting the building and windows in the best direction would reduce the mechanical air-conditioning requirement. The potential of shading devices is reported to reduce vary from 10% to 50% . A 30% reduction in the primary energy demand was achieved by optimizing the design of shading device , solar heat gain through the roof was reduced by 63% using hollow clay tiles. [12].

Wood and bamboo are examples of eco-friendly materials which are excellent in absorbing heat and allowing natural ventilation thus giving comfort to the occupants. The bioclimatic building design is essential for a building to adapt to local climates and to provide comfort for the inhabitants while encouraging energy saver features. Comfort inside the house can be

achieved with less dependence on artificial lighting and mechanical ventilation, and the application of eco-friendly materials. [10]

Bioclimatic design approach that gets ideas from the vernacular architectures uses of the passive design of a building to achieve a certain comfort level with as minimal use of energy and low carbon emissions. The house was built using environmentally friendly local materials that allow natural solar protection, natural ventilation, and natural lighting and the approach of Indonesian vernacular architecture that focuses on shape-natural-energy to achieve comfortable thermal interior of the building with focus on four factors, wind orientation, climate, solar radiation and materials [10].

4. Site Observation and Analysis

Site observation and analysis is the first step for the holistic design process. The understanding of the site and the nature surroundings are the soul of whole process and as part of the integrated architecture and landscape design. The landscape has been put as an appropriate unit for holistic approaches to management[14] that would cause to the cost of electrical and more.

A site study must be made to determine wind directions and sun path, as drawn in Figure 1, to design the orientation of the building and the location of openings. In terms of solar radiation, the north-south orientation is an option since east-west orientation receives maximum solar radiation. A study conducted on the climate of the site can assist the process of implementing suitable bioclimatic design and materials selection [10].

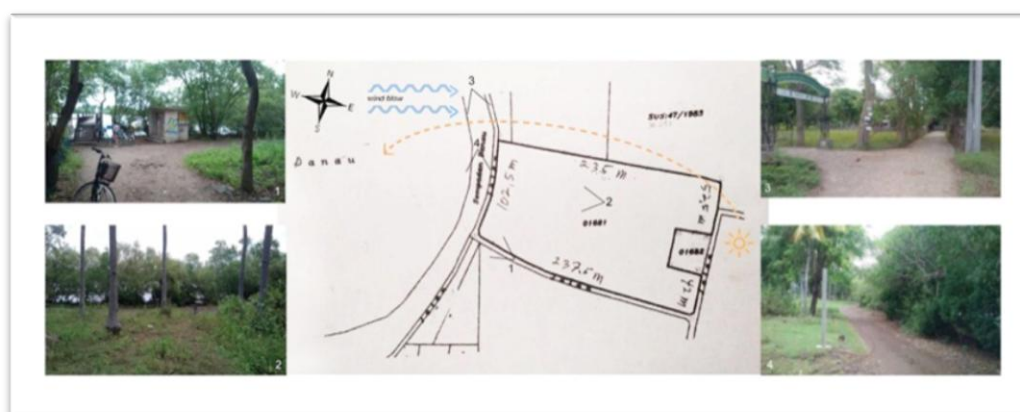


Figure 1. Sun path and predominant wind direction of the project site

5. Bamboo Type

Bamboo can be used in a wide range of project types. Bamboo elements can also be used as both the structural system and the wall and roof cladding [15]. The study between bamboo and brick material as alternative to night cooling strategy for houses has been suggested by vernacular architecture approach of using bamboo for the wall and floor system, the study demonstrates that building material has an important role in order to create a thermally tolerable indoor environment for hot-humid climate condition [16].

Research of the use of bamboo as indigenous material claimed that native plants were already adapted to the local conditions as well as benefit for the ecology [17] and also has its character that is quite similar to hardwood. Bamboo culm is composed of 50% parenchyma, 40% fibers, and 10% conducting cells. The major chemical compositions of bamboo are cellulose, hemicellulose, and lignin, which amount to 90%. The minor compositions that amount to 10% called extractives are composed of resins, tannins, waxes, and inorganic salts, this component makes bamboo have a quite similar to hardwood species [1].

Without treatment, bamboo durability is less than 2 years, and it could be considered as its weakness. According to Indonesian local belief, it may last more than 10 years condition [18]

and the use of preservation of borax boric [19] will have a life expectancy of 40 years, and has been proved robust enough to withstand earthquakes [20] but it needs further research to claim it as a sustainable way of preservation.

Culm bamboo has been chosen for this project as part of architecture building material and landscape element for the whole project. Sympodial bamboo which grows in the tropical island [21], *Gigantochloa Apus* (J.A. & J.H. Schultes) Kurz (Apus Bamboo) has been chosen for wall and roof for its characteristic of culm thickness and its length and distance of node and *Phyllostachys Aurea* A. and Ch. Riviera (Cendani Bamboo) for ceiling and passive shading for its small diameter of culm, *Gigantochloa Atroviolacea* Widjaja (Black Bamboo) for 'living' shading for its not so height culm and its beautiful culm's color [19].

The culm is the upper ground part of bamboo containing most of woody material. The culm is naturally straight, hollow, and cylinder-formed with nodes and internodes with hollow inside, which forms bamboo cavities [1] that made bamboo as material with cylindric layers to absorb heat as drawn in Figure 2.

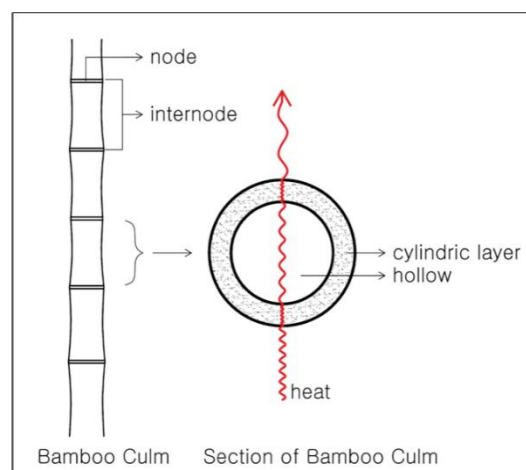


Figure 2. The hypothesis bamboo as heat insulated

6. Design process

As the whole complete project, the project will be planned into more than two phases. As the first plan, it is divided into two phases of design. Phase one is six units of one-storey villa and phase two is three units of two-storey villa.

6.1. Site location of phase 1 and phase 2

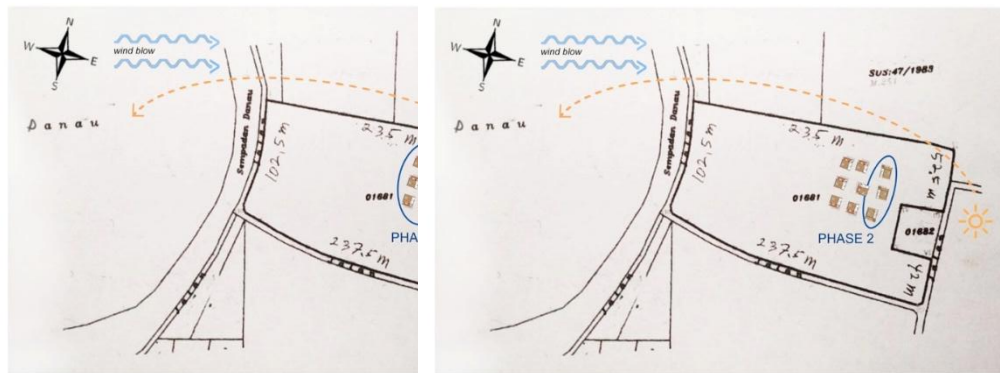


Figure 3. Site location of phase 1 and phase 2

6.2. Design Development

This project adopted the concept of bioclimatic building design by using bamboo as indigenous material for wall, ceiling, roof and shading. Cooling energy is influenced by the external gain from their envelope [2].

The design of the villa started with the orientation of the villa. Glass wall (c at Figure 4,5,6 and 7) for large transparent view is facing North-South, while the bamboo wall (a at Figure 4,5,6 and 7) is facing East-West. Glass wall that facing East-West have a 'living' shading of Sympodial Black Bamboo (b at Figure 4). Open air window is facing to East -West to be cross ventilated and the narrow side of terrace is facing to East-West to get moderate wind blow from the lake. It is applied to five villas on the first phase (Figure 4 ,villa type 1, 2, 4 and 5) except villa in the middle (Figure 4, villa type 3) it is rotated in opposite with consideration of shading from the surrounding villas.

The second floor of villa type 4 and 5 (Figure 6) on the second phase are applied the same orientation consideration with passive shading added for the open terrace of the bedroom to minimized the heat because it is located higher than the first phase.

There is two types of bamboo shadings in this project, first is a bamboo 'living' shading (b at Figure 4 and 6), as part of landscape using the Sympodial Black Bamboo. The landscape is an appropriate unit for such holistic approaches to management [14]. Green space has demonstrated associations with health that are independent of quality of green space or perceptions of such space by participants[11]. Second, the passive shading (d at Figure 7) for terrace using Cendani Bamboo culm as an approach of passive design of Bioclimatic design.

The ceiling (e at Figure 5, 7 and g at Figure 7) is using culm bamboo, roof (f at Figure 5 and 7) is using half culm bamboo overlapped each other as heat insulated.

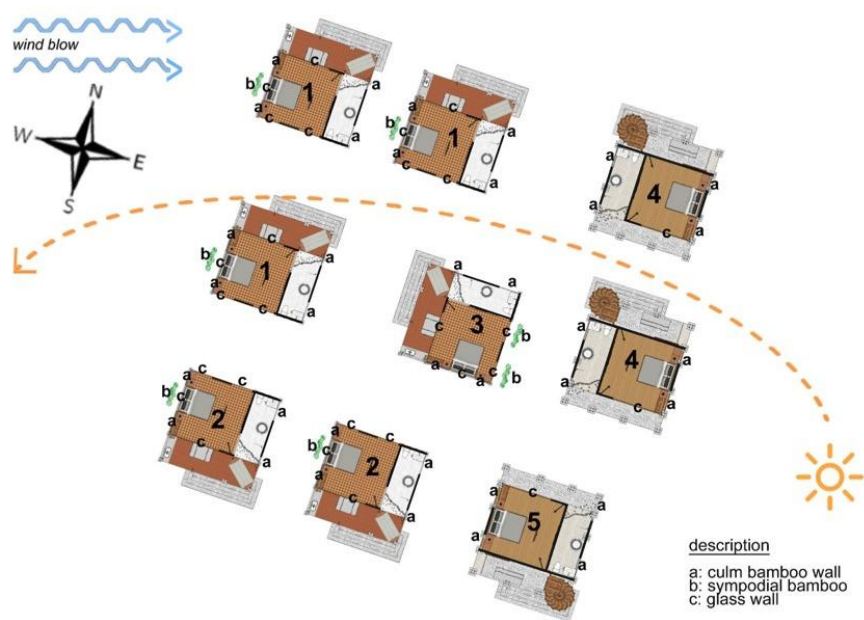


Figure 4. Layout development of phase 1 and first floor of phase 2

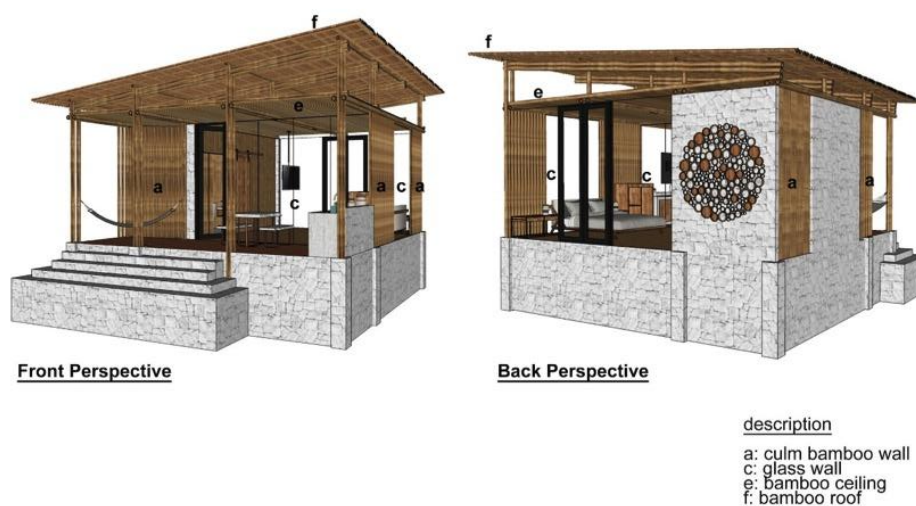


Figure 5. Design development of phase 1

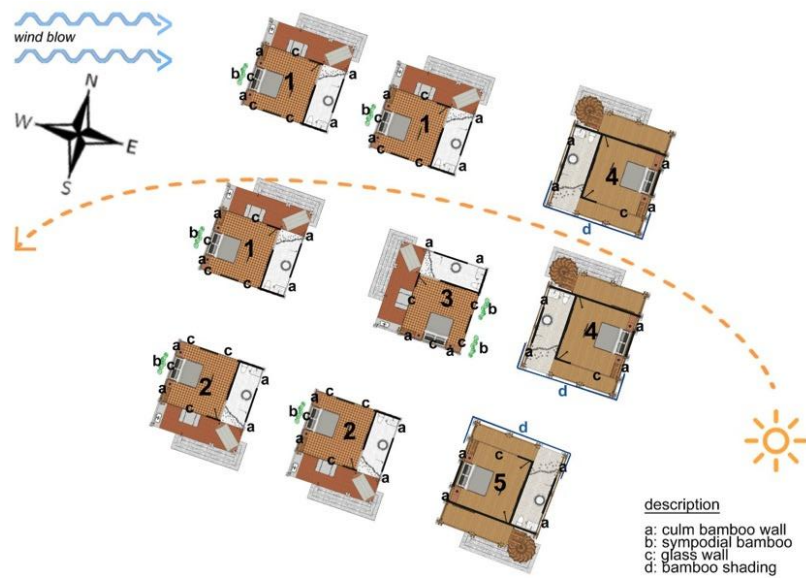


Figure 6. Layout development of phase 1 and second floor of phase 2

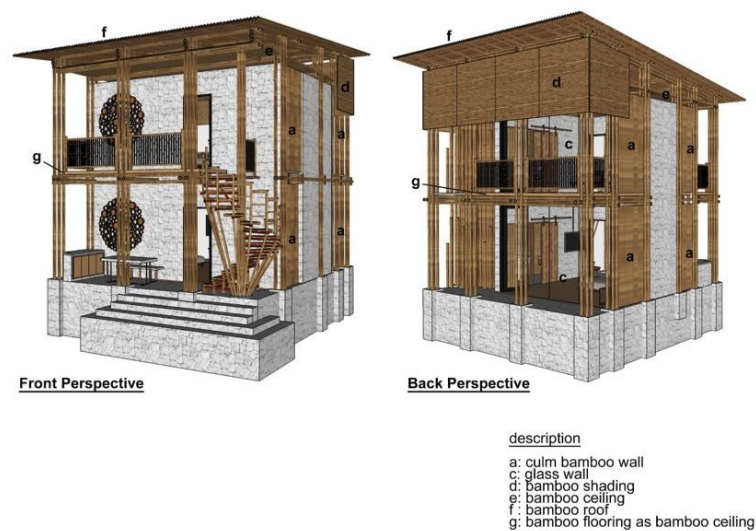


Figure 7. Design development of phase 2

6.3. Expected results of comfort thermal performance inside the villa of phase 1 and phase 2

The use of Apus Bamboo culm for the wall, ceiling, roof and Cendani Bamboo for passive shading as part of holistic architecture design element and building material and Sympodial Black Bamboo for 'living' shading as part of holistic landscape with orientation consideration of sun path and predominant wind direction are expected to create thermally comfort interior environment.

7. Conclusion and Suggestion

The combination use of the bamboo culm in architecture design for wall, ceiling, roof and shading will be expected to create thermally comfortable interior environment for one-storey and two-storey villa.

The understanding of the nature by positioning the glass wall on the north-south orientation with Sympodial Bamboo as a 'living' shading as part of landscape and the use of bamboo culm for shading on east-west orientation in front of glass will be expected to support the use of bamboo culm in architecture design for maximizing the comfort thermal inside the villa.

The use of bamboo as a sustainable indigenous material in architecture design and landscape to create thermally comfortable interior environment is a part of holistic design approach in tropical island.

The findings suggest that the use of culm bamboo for a wall, ceiling, roof and shading for the one-storey and two-storey buildings and the use of Sympodial Bamboo for 'living' shading could lead to a thermally comfortable indoor environment. The finding needs further research to compare the indoor microclimate conditions using thermal comfort Predicted Mean Vote and Predicted Percentage of Dissatisfied models (PMV-PPD) developed by American Society Heating, Refrigerating and Air-conditioning Engineers (ASHRAE).

Further research also needed for the application of natural material in its genuine form for example bamboo culm for promoting psychological comfort and the use of borax boric to preserve bamboo will maintain the nature environment of sustainable characteristic of bamboo.

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