

Preliminary Study of Green Material for Green Building in Bali

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Abstract The definition of green materials is building materials that are environmentally friendly, do not have a negative impact on building users, and are sustainable. Green Material is one of the criteria in the green building assessment parameters that will support energy efficiency goals. Understanding green materials and their availability for their demands in Bali is important to align the growth of green buildings in Bali with the potential and problems of material supply. This paper aimed at conducting an initial preliminary study of the limitation and opportunities for the use of sustainable building materials according to the green building principle approach in Bali. The method used is descriptive method that is reinforced by literature review techniques related to the context of the discussion. Buildings in Bali, when viewed from the use of building materials, carry very distinctive design and appearance characteristics. The selection of green materials in Bali will be influenced by the demands of the requirements for implementing Balinese architecture in buildings, restrictions on material procurement due to location, material legality references and ecolabel certification documents and opportunities for using smart and advanced materials without losing the character of Balinese building architecture.

Keywords: *Green Material, green building, sustainable building material*

I. INTRODUCTION

Sustainable development is one solution to how buildings are responsive to the impacts of climate change. Green buildings are part of the realization of sustainable development that focuses on applying the principles of green architecture to buildings. According to World Green Building Council (WGBC) [1], a green building is a building that, in its design, construction and operation, reduces or eliminates negative impacts and can create positive impacts, on our climate and natural environment. Green buildings are expected to be efficient in energy utilization, minimize adverse impacts on the environment, support the sustainable availability of natural resources and improve the quality of human life as users.

In general, there are several principles that can be applied to make a building fall into the green building category. Some of these principles include: (1) efficient use of energy sources, water and other natural resources, (2) utilization of renewable energy sources such as solar energy, (3) reducing pollution and waste and encouraging re-use and recycling, (4) improve health and air quality in indoor spaces, (5) use of non-toxic, regulatory and sustainable building materials, (6) pay attention to environmental impacts and the design, construction, and operational stages, (7) pay attention to the quality of life of its users and (8) plan

a building design that allows adaptation to environmental changes.

Of the several principles mentioned above, the use of sustainable materials is one that must be considered in realizing green buildings. Usually, the choice of material in a building that is the most important consideration is the cost that must be incurred for the supply of the material in question. However, this purchase cost only shows the cost of production and transportation, not the cost of social and environmental impacts [2]. This is one of the considerations in the green material concept. The choice of material is also closely related to the passive design of green buildings. The choice of material will be related to the ability of the materials used to support the performance of green buildings, especially for energy efficiency and to improve the quality of life of its users.

If we refer to several green building assessment tools from various countries in the world such as Leadership in Energy and Environmental Design (LEED) from U.S Green Building Council as most widely used rating system, and BREEAM from UK, Green Star (Australia), Green Building Index (Malaysia), CASBEE (Japan) and several others, the green material aspect is an important aspect in the assessment of green building certification [3][4][5]. Similarly, if seen in the assessment parameters that exist in Indonesia such as Greenship 1.2 from Green Building

Council Indonesia (GBCI) [6] and Rating Tools from Ministry of Public Works and Housing (PUPR) [7], material components are also an assessment in green building certification.

The concept of green buildings began to be applied in Bali through the initiation of the Ministry of PUPR and the Regional Government of Gianyar Regency which politically directed the application of green building principles and certified green buildings in Sukawati market buildings in Gianyar which are public commercial building. From this initiation will leads to the widespread application of green building principles in Bali in the future and will be used in more buildings, both government and private buildings. From the development of green building application that has begun to be carried out in Bali, it is very important that the parameters of this assessment are further understood.

As a first step, a general review of each component related to the requirements for implementing green building principles needs to be carried out so that stakeholders involved in realizing green buildings have a basis in making decisions related to achieving energy efficiency goals, improving the quality of life and sustainable development. The general analysis carried out at this writing was on the parameters of green material. This general study describes the opportunities, limitations and alternatives to the application of green materials for green buildings in Bali.

II. RESEARCH METHOD

The purpose of this paper is to conduct a preliminary analysis of the limitations and opportunities for the use of sustainable building materials according to the green building principle approach in Bali. Buildings in Bali, when viewed from the use of building materials, carry very distinctive design and appearance characteristics. The use of renewable natural materials is an integral part of showing the character of traditional Balinese architecture in its appearance [8]. When the development of functions leads to building types that are included in the scope of green buildings such as office, commercial buildings (shopping centers), meeting halls, or exhibition buildings, hospital buildings, museums, educational buildings, flats, apartments, and hotels, which are sophisticated multi-storey residential buildings [9], the character of this traditional Balinese architecture must be maintained. The selection and alternative application of green materials is a matter that specifically influences the realization of green buildings in Bali. Therefore, preliminary studies are important to do to provide an overview of the building materials used to support the success of green buildings in achieving their goals, namely energy efficiency.

The method used is a descriptive method that is reinforced by literature review techniques related to the context of the discussion. By conducting a study of literature related to the context of the discussion alone will make the study more referenced and targeted despite using a limited database of literature.

III. DISCUSSION

A. The review of green material as sustainable building material

In general, green materials are building materials that are environmentally friendly or have no adverse impact on the environment, user health and sustainability [10][11][12]. But further, the understanding of green materials is not limited to building materials that are environmentally friendly but will also be related to aspects of the origin of the material, the production process, transportation and installation in buildings. study the use of materials from start to finish is called material life cycle analysis [6][7][13].

When viewed from the perspective of sustainable building materials and life cycle materials, the materials will be differentiated based on three development phases, namely pre-building phase (PreBP), building phase (BP) and post-building phase (PostBP). There are several features to consider in choosing a material [2] and will be shown the relationship with the building phases in table 1 below.

Table 1. Relation between building phase and sustainable feature of material

Sustainable Feature	PreBP	BP	PostBP
Pollution Prevention Measures in Manufacturing	√		
Waste Reduction Measures in Manufacturing	√		
Recycled Content.	√		
Embodied energy reduction	√		
Use of natural material	√		
Reduction of construction waste		√	
Local materials		√	
Energy efficiency		√	
Water treatment and conservation		√	
Use of non-toxic materials		√	
Renewable energy systems		√	
Longer life		√	
Reusability			√
Recyclability			√
Biodegradability			√

Source : Kim and Rigdon, 1998

References related to green material criteria from different source and environmental impact perspective can be seen in Table 2 below [14]

Table 2. Environmental material criteria for green building

	Criteria/variables	Description
1	Low toxicity	Material with reduced toxicity or non-toxic concentrations
2	Minimal Emissions	Product with low or no chemical emissions (VOCs, CFCs)
3	Low VOCs concentration	Reduce the amount of indoor air containments
4	Recycled content	Products with identifiable recycled content
5	Resources efficient	Products manufactured with reduced energy consumption wastes and GHGs
6	Recycleable materials	Materials recycleable at the end of their useful life

7	Reusable components	Building components that can be reused
8	Sustainable sources	Renewable natural materials harvested from sustainable sources
9	Durable materials	Material comparable to conventional with long life expectancies
10	Moisture resistant	Products that resist to moisture or inhibit the growth of contaminants
11	Energy efficient	Material that helps reduce energy consumptions on building s
12	Water conserving	Products and sysrems that help reduce water consumption
13	Improved Indoor Air Quality	Systems or equipment that promote healthy IAQ
14	Healthful maintenance	Material that require simple and non-toxic cleaning
15	Local product	Regional materials saving energy and transportation to project site
16	Affordable material	Building cost comparable to conventional material

Sumber : Froeschle, 1999 dalam K. I. Vatalis, 2013

B. Learn from Material selection in Balinese Traditional Building

Implementation of natural material within parts of building structure is a common practice in Balinese Traditional Architecture. According to Sulistyawati (2013) [15], these natural material include thatch, sugar palm tree's black fiber, roof tiles, bricks, natural local stone such as *batu padas* and timber. The material type according its installation on part of building structure such as:

a. Material for roofing

Alternatives to traditional roof coverings are shingles, *alang-alang* and palm fibers. *Alang - alang* is a type of roofing material at the early stage and then develops using palm fibers for classifying buildings that are higher than residential, for example for holy places. A more modern and currently widely used roof covering material is clay tile.

b. Material for walls and columns

In traditional Balinese buildings, red bricks and *polpolan* soil are used for the walls. For wall ornamentation, red brick and solid stone carvings are also often used. As for the building columns, in general, use wood. The wood used also has a level according to the type of building that uses it. For example, building a holy place (temple) will use the highest level of wood species such as sandalwood, chrysolite and *majegau*.

c. Material for foundations

Alternative materials for traditional Balinese sub-structures include materials such as brick, solid stone, river stone, limestone and more modern alternatives such as concrete.

The building material approach in Balinese architecture must not only fulfill physical requirements but also fulfill the use and placement according to its various functions in the building. For the harmony of the human relationship with the natural environment, the procurement of this material is made as much as possible from materials that exist in the environment around the building [16]. Materials used for building foundations, for example, use natural stone from the environment around the building site.

Villages near the river use river stone foundations, villages near the limestone hill areas use limestone as a foundation material and areas with other natural rock source characteristics will try to adjust the availability of nearby materials.

Another example is the selection of alternative roof covering materials which also adjusts to the availability in the immediate environment. Areas that are in the mountains with adequate bamboo availability will use bamboo shingles for roof coverings, but if the area is close to rice fields, it is predominantly using *alang-alang*. Likewise, if using other alternative roof coverings such as palm fiber and woven coconut leaves, it will also be seen in the nearest location.

Traditional Balinese buildings also often display materials with their own characteristic. For example bricks and other natural stones will be installed in their original state. Wood, bamboo, roof covering materials such as *alang - alang* and palm fibers are installed in their natural state and show their natural color textures. The diversity of colors, the layout of the building components, textures, proportions, and compositions in such a way as to form a series of beautiful Balinese architectural aesthetics..

C. Green Material Criteria based on government regulations on Green Building

Referring to the Regulation of the Minister of Public Works and Housing (PUPR) No. 2 in 2015 [17], regarding Green Buildings, one of the principles is that Green Buildings must reduce the use of resources, in the form of land, materials, water and other resources. Furthermore, the requirements at the technical planning stage of the building place great importance on the use of local, environmentally friendly materials that are not dangerous and are proven by environmentally friendly certificates (eco-labeling).

In more detail, understanding environmentally friendly materials according to technical guidelines for building operations (Surat Edaran no. 86/SE/DC/2016)[18], environmentally friendly materials with two general conditions can be described in more detail as follows:

1. Control of hazardous materials

Control of the use of hazardous materials that can interfere with the user's health and even cause cancer (carcinogenicity). Control through the selection of materials used as dominant roof coverings, wall paint finishing materials, renewable wood or bamboo materials, and metal materials. For renewable wood materials, the focus is on the use of adhesive (glue) so that it is ensured that it does not endanger the user's health.

2. Use of certified environmentally friendly materials

This requirement arises with the aim of protecting environmental sustainability from the side of the producer of raw materials. Supporting documents are Sertifikat Manajemen Lingkungan (SML), wood legality certificate, and material product eco-label certificate. Materials that need to be supported by this certificate include structural materials (sand and gravel), preferably local, cement materials, wall covering panels, renewable wood or bamboo materials, paint and roof coverings.

Apart from the two things described above, related to materials, it is a must to pay attention to the principle of the

life cycle time by considering the use of materials in buildings, selection of suppliers, and energy conservation. Efficient use of materials to minimize material waste is also something that must be considered. The selection of material suppliers is made as close as possible to the project location to minimize the use of non-renewable energy for transportation.

D. Green material according to rating tools of Green Building Certification

To ensure a building meets the elements of attainment of green building parameters, it must go through a certification process. In this discussion, the green material criteria will refer to the assessment parameters in the rating tools used by the Green Building Council Indonesia (GBCI), which is an affiliate of World Green Building Council. The newest rating tool currently in use is GreenShip 1.2 [6].

In the GreenShip 1.2 green building assessment, the fourth category is Material Resources and Cycle (MRC). In this category, there are 1 prerequisite and 6 criteria. The explanation is as follows

1. Prerequisites Fundamental Refrigerant

This requirement relates to the non-use of Chloro fluoro carbon (CFC) for air conditioning refrigerants and halon gas for fire extinguishing agents. These two materials are categorized as hazardous materials because they destroy the ozone layer. Damage to the ozone layer is one of the causes of global warming and climate change.

2. Building and material reuse criteria

The reuse of used materials either from old buildings or from other places aims to reduce the use of new raw materials, extend the life of materials and reduce waste of building materials. The reuse of used material that scores in this criterion is if the percentage of material reuse is equivalent to 10% - 20% of the total material cost

3. Environmentally friendly processed material criteria

This criterion aims to reduce the adverse impacts from the ecological side related to the process of obtaining raw materials and the entire process of making the materials until they are ready for use. The benchmarks used are materials that have an environmental management certificate in the production process, using materials that are recycled and materials whose main raw materials come from renewable sources with a short-term harvest period of under 10 years.

4. Non Ozone Depletion Substance (ODS) usage criteria

This criterion is about green buildings not to use materials that have the potential to damage the ozone layer. The emphasis is on the entire building cooling system should not use HCFCs.

5. Certified wood criteria

This criterion aims to protect the sustainability of the forest as a source of wood. In green buildings, it is hoped that the wood used is timber with a legal certificate of the origin of the wood as evidenced by a processed wood transportation invoice document (FAKO), a company certificate and does not include illegal trade.

6. Prefab material criteria

Prefabricated materials are one of the ways for material efficiency and reduce waste generated during the

construction stage. The green building is expected to use 30% prefabricated modular material. Types of fabrication materials that are commonly used are aluminum composite panels, glass, concrete - prefab concrete for building structures on floors, columns, walls and roofs, and modular partitions used in interiors.

7. Regional material criteria

The use of local materials aims to reduce the carbon footprint of transportation means during transportation and encourage the growth of the domestic industry. Green buildings are required to use materials where the location of the main raw materials and the factory is in a radius of 1000 km from the location and prioritized the origin of the raw materials is in the territory of Indonesia or not imported materials.

IV. FINDINGS

A. Demands Requirements for Balinese Architecture on Buildings

Buildings in Bali must have the characteristics of the application of Balinese Architecture and are regulated in Regional Regulations related to Building Architecture requirements [19]. These architectural requirements are related to the shape and character of the appearance of the building, its interior, and its harmony with the environment. The definition of traditional Balinese architectural style according to this regional regulation is a style of architectural appearance that can provide an architectural image based on Balinese culture that is imbued with Hinduism through the application of various principles of forms that contain identity and values of traditional Balinese architecture.

The building material aspect is also mentioned in the regional regulations mentioned above where the use of local building materials is prioritized by paying attention to the color and texture of the building which is in harmony with the environment. The main objective in the material selection process to be used is to strengthen the reflection of the traditional architectural identity in the embodiment of the building, especially in the appearance of the building façade as its appearance.

Specifically, for the use of wood when referring to wood commonly used in traditional Balinese architecture, there will be problems related to material availability and potential scarcity in the future. Then the choice of wood is given a choice that is considered equivalent to the level of wood according to traditional norms such as jackfruit wood which can be replaced with *Merbau* wood, teak wood can be replaced with *bangkirai* wood. In addition, the use of technology in wood processing and utilization is also permitted for the purpose of strength, durability, and aesthetics of wood materials in buildings. Another material that is considered to support the character of Balinese architecture is the use of natural stones such as sandstone, river stone, brick, limestone, and other local stones. Mini-style stones can be installed on the building facade or on the walls around the building.

In a regional regulation in a smaller scope, namely in the city of Denpasar, the aspect of building materials appears in the discussion of the principle of decorative style [20]. The decoration required in buildings is the traditional decoration that blends well in the appearance of the building. The materials used in building decorations should be organic or natural materials such as bricks, sandstone, and other natural stones. The application of this decoration starts from the roof of the building in the form of *bentala* and *ikut celedu* decorations, on the body of the building wall with patches or ornaments and on the legs with *pepalih* or natural material belts.

B. Limitation of Green Material Procurement in Bali

The condition of procurement of building materials in Bali is not the same as the procurement of materials in Java, the main island of Indonesia. Several different conditions are that there is no factory for building materials such as ceramics or cement or paint. The majority of those available in Bali are distributors of building materials. The issue of embodied energy and carbon print will affect the choice of materials to be used in green buildings in Bali.

This requires special attention regarding the issue of using fuel, which is a non-renewable natural resource for transportation from the factory to the distributor then to the site or from the factory directly to the location. If you refer to one of the measured distances used in the green building criteria from GBCI [6] the distance limit that is still in the criteria is 1000 km for the larger points and is still within the scope of the Indonesian state for the next point. So for the procurement of materials from outside Bali it is necessary to limit the island to Java to the west and to East Nusa Tenggara from the eastern part if it is related to a distance of 1000 km. The use of imported raw materials should no longer be used in green buildings in Bali.

The philosophy of using local building materials has been reflected in the traditional material selection approach in Balinese Traditional Architecture. This is in line with the philosophy of the material aspect of green buildings. This shows that traditional Balinese architecture already has the same sustainability principles as the green building principles. And this is one of the strengths of green building in Bali and is regulated in the building requirements regulations in Bali.

Meanwhile, the availability of local materials such as sand and stone for building structures, alternative natural stone to be installed on the facadem and bamboo, and some types of local wood still exist whose source location is in Bali. For wood, most of the sources are outside Bali and it is necessary to confirm the legality of the materials to be used through environmentally friendly documents and certification. Furthermore, it is necessary to collect data on what local building materials are in good availability related to sustainability.

C. Procurement of certified legal materials

Certifications or documents that show the legality of building materials, especially wood, are very important in the

selection of materials to be used in green buildings. It is very important for material users to understand where to find information or see the validity of the documents used to show the material in question is environmentally friendly material.

As mentioned above, several documents that can be referenced to demonstrate the legality of the material are environmental management certificate (SML), wood legality certificate and eco-label certificate for material products. Documents regarding the legality of timber such as a Processed Timber Transport Invoice (FAKO) which can show the legality and source of the wood in question [21]. Meanwhile, the international standard ISO 14001 regarding the environmental management system (EMS) owned by a company or material producing industry can also be a document that shows that the company has reached the required standards regarding its environmental impact management. More details can be seen on the web <http://standardisasi.menlhk.go.id/wp-content/uploads/2016/11/Leaflet-ISO-14001-SML.pdf>

There are several other institutions that can also be sources of information regarding alternative materials that meet environmentally friendly criteria such as Certification from the Indonesian Ecolabeling Institute which is seen on its website <https://lei.or.id/> and information sources related to environmentally friendly building materials from Green Products Council Indonesia (GPCI) on page <https://gpci.or.id/>. Both of these institutions are non-profit organizations engaged in environmentally friendly certification and Associate Member of the Global Ecolabelling Network (GEN). GPCI was established to encourage all people to pay attention to environmental aspects in the use of green and environmentally friendly building material products. Types of materials that have been certified and meet the criteria of environmentally friendly or green materials include types of ceramic or granite tiles, gypsum board, cement board, paints and coatings, sanitary tools, pipes, light steel and steel, glass, aluminum and cement mortar.

D. Considerations for the application of more sophisticated building materials (advanced green material)

The façade design of Balinese buildings is generally filled with the application of natural stone which dominates the majority of its area [21][8]. Installation and maintenance of natural stone also carries the potential for the use of chemicals that can harm the user's health if using adhesives that contain ingredients that are harmful to health. The choice of adhesive material needs to validate its ecolabel so that it can be ascertained that it is safe for the user.

An alternative to using other cutting-edge materials on the facade that is in line with the principles of green building is the use of glass to minimize energy use in buildings. Glass is a smart material in green buildings, especially glass with low emission characteristics or called Low-e glass and glass with light reflective power called reflective glass [22]. A low-E or low emissivity coated glass consists of a thin invisible layer, metal or metal oxide layer deposited on the glass pyrolytically (hard coat) or in a vacuum coater (soft coat). Low-e glass is able to reduce heat

entering the building which indirectly reduces energy consumption for cooling and affects user comfort in the room.

The use of photovoltaics is an alternative source of energy that is widely used in green buildings. With solar cells in photovoltaic panels, sunlight that produces heat is converted into electrical energy [22]. Given that green buildings, one of the focuses is energy efficiency, the use of photovoltaic panels will be an important breakthrough to be applied to green buildings in Bali. This solar panel placement is generally placed on the roof of the building to maximize solar heat absorption.

Facades are important in buildings in Bali because they are a manifestation of the Balinese architectural identity [23]. The use of this cutting-edge material should still consider the need for changes to the Balinese architectural identity on the facade and the composition of the building so as not to lose its local character. The effect of using glass, for example, will greatly affect the facade of the building on the body of the building. The percentage of the glass area needs to be considered so as not to dominate too much and to eliminate the opportunity for decoration on the facade. The use of solar panels will affect the appearance of the roof and the appearance of the building as a whole. Placement of solar panels on the roof must be planned in such a way as not to interfere with the appearance of architectural identity but still function optimally.

V. CONCLUSION

Discussing green materials will include materials that have environmentally friendly characteristics. This will be closely related to sustainability where the current use of materials does not interfere with the availability for future generations. To see material classification and categorize as green material, one cannot only look at the final product but must pay attention to several things such as how much energy is used to produce the material, how much volume of waste is generated from the production process. When installing or using it, it is necessary to pay attention to how much energy is needed for the material to function optimally in the building. Then at the end of its optimal use period, it is also necessary to see whether there is potential for reuse or must be immediately discarded without being able to be recycled. The advantages that users get when using green materials are reducing costs in maintaining buildings or replacing materials, supporting energy efficiency in buildings, supporting user health and design flexibility [10].

For the selection of green materials that will be used in buildings in Bali, there are several things that can be concluded and need to be considered, namely:

1. Selection of green materials must be based on the needs of building design characteristics by applying the principles of Balinese architecture while at the same time supporting the achievement of the objectives of applying the principles of green building in Bali.
2. Maximize the use of local green materials available in Bali to ensure a small carbon print.

3. The selection of alternative green materials to be used must still refer to the legality supporting documents and ecolabel in accordance with the green building assessment criteria parameters.
4. The use of smart materials and materials with high technology needs to pay attention to how it affects the appearance of the building appearance and shape. This is important because the dominant Balinese architectural identity is identified from the appearance and shape of the building.

The study carried out this time is still a very general study and not discussing the direct relationship of the use of certain materials to the effectiveness of green buildings in Bali. Furthermore, it is necessary to carry out a more focused stage of research to identify the availability and potential for procurement of building materials. Research related to the effect of material limitations in Bali on the performance of green buildings is a topic that needs to be further explored.

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