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Future Architecture Sustainability through Green Design Principle in Sade Vernancular Settlement

Alya Nafisa Fidelista*[1], Agung Murti Nugroho[2], Bagus Fajar Novianto[2], Diana Savitri[2], Muhammad Hafizh Ramadhan[2], Infaroyya Al Karimah Muhammad[2]
[1]Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia
[2]Universitas Brawijaya, Malang, Indonesia

Correspondence Author
*alya.fidelista@its.ac.id

ABSTRACT
Climate change poses pressing design and environmental challenges, addressable through time-tested vernacular architecture. The Sade settlement on Lombok exemplifies enduring green design practices worth examining for modern applications. This study employs a systematic literature-based methodology: reviewing green architecture benchmarks for an overview; analyzing studies on Sade Village's physical forms; identifying links between general green criteria and local implementations; and formulating principles for future general and vernacular architecture. Using descriptive-evaluative methods, it assesses design elements against eco-friendly standards. Key findings reveal Sade's strengths, including compact, contour-parallel building masses with linear circulation; north-south orientation for optimal passive lighting and ventilation; regulated heights with lightweight, hollow local materials for humid tropical and seismic resilience; ample green open spaces to counter urban heat islands; and nature-responsive site utilities. These principles demonstrate adaptive, ecosystem-sustaining design. The research yields actionable recommendations for integrating such green design principles into future architecture, particularly preserving and enhancing them in Sade and similar vernacular contexts to support long-term environmental sustainability.
Keywords: *Green Design Principle; Sade Vernacular Settlement; Architecture Sustainability*

INTRODUCTION
Vernacular architecture is part of sustainable architecture. Green architecture plays a vital role within the framework of sustainable architecture, in which there are three main essential elements of green buildings; environmentally friendly (soil, water and air), energy friendly and human friendly. Sasak architecture grows and develops in the traditional Sasak community on Lombok Island so that it becomes part of the Nusantara's vernacular architecture. Potential natural resources, social, cultural, economic, environmental, and historical aspects of Sasak architecture uphold the values of local wisdom. This underlines our research to discover more about the characteristics of green architecture in Sasak architecture.

Susilo et al. (Susilo, 2019) explained that Sasak architecture on the island of Lombok consists of two types, namely hilly Sasak architecture (traditional houses in Sade, Eastern Limbungan and Western Limbungan village), as well as flat ground Sasak architecture (traditional houses in Senaru, Beleg-Gumentar village). Buildings in Sasak architecture are oriented towards the hills parallel to the contours, while Sasak architecture on flat land has a building mass orientation perpendicular to Mount Rinjani. Sasak architecture is the architecture of a mass of buildings, where the existence of buildings is interrelated in the context of a house.

This study aims to determine aspects of air conditioning, lighting, water management, energy utilisation and the use of sustainable building materials to formulate recommendations on green design principles for future architecture, especially in Sade Settlements and vernacular settlements in general.

PREVIOUS RESEARCH

Green architecture is an effective way to achieve future goals regarding sustainability between people, buildings and the environment. This building and environmental design have a very influential effect on society, starting from the economic, social and environmental aspects. Green and sustainable buildings that depart from the local environment can be a healthier solution and save local resources (Ragheb *et al.,* 2016; Mohammadabadi *et al*, 2011).

Vernacular architecture is a form of expression of a society's civilisation in dealing with the environment in which it lives (Agyekum *et al.,* 2020; Singh *et al*., 2009). One region to another can produce different forms of vernacular architecture. Research conducted by (Philokyprou *et al*., 2017) in Cyprus regarding vernacular buildings shows that one small island country can produce different typologies of houses because they are separated by three climatic zones, namely the coast, lowlands and mountains. Therefore, vernacular architecture is the best source to explore the criteria for green architecture.

From a literature search related to vernacular and green architecture, a summary of the general criteria for green architecture is obtained as follows:

Table 1. Green Building Criteria

No	Literature	Criteria
1	Ragheb. A, El-Shimy. H, and Ragheb. G, "Green Architecture: A Concept of Sustainability," Procedia - Soc. Behav. Sci., vol. 216, 2016, doi: 10.1016/j.sbspro.2015.12.075..	Sustainable site design. Water conservation and quality. Energy and environment. Indoor environmental quality. Conservation of materials and resources.
2	Mohammadabadi. M. A, and Ghoreshi. S, "Green architecture in clinical centres with an approach to Iranian sustainable vernacular architecture (Kashan city)," in Procedia Engineering, 2011, vol. 21. doi: 10.1016/j.proeng.2011.11.2053.	Site selection and landscape. Energy and ventilation. Water management. Pollution management. Resources and material quality. Inner space quality.
3	Xu. H, Liu. Z, Wu. C, Zheng. J, and Zuo. L, "The research on sustainable technology of the traditional house in the Southern area of Hubei province," J. Asian Archit. Build. Eng., vol. 19, no. 4, 2020, doi: 10.1080/13467581.2020.1749640.	Energy saving in building construction: Courtyard: ventilation, daylight, drainage; Wall: resist foreign enemies, fire prevention, heat preservation.
4	Agyekum. K, Kissi. E, and Danku. J. C, "Professionals' views of vernacular building materials and techniques for green building delivery in Ghana," Sci. African, vol. 8, 2020, doi: 10.1016/j.sciaf.2020.e00424.	Local material for sustainability (wood, bamboo, dan laterite.)

Source: (Ragheb *et al.,* 2016; Mohammadabadi *et al*., 2011; Xu *et al*., 2020; & Agyekum *et al.,* 2020)

From the literature summary above, all the criteria obtained can be synthesised to formulate green building criteria in general.

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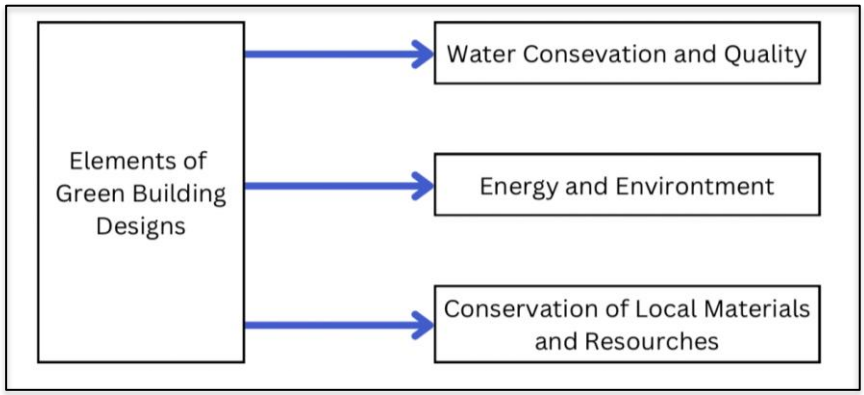

Figure 1. Synthesised Green Building Criteria
Source: Authors' Documentations (2024)

METHODS

This research employs a systematic literature-based approach to derive green design principles from the Sade vernacular settlement. The process unfolds in four sequential steps: first, a comprehensive review of green architecture literature provides foundational criteria and benchmarks. Second, targeted analysis of existing studies on Sade Village elucidates its distinctive physical architectural features. Third, alignments are identified between universal green building standards and their practical manifestations in Sade. Finally, these insights are synthesized to formulate adaptable green design criteria for both general and future vernacular architecture.

FINDINGS

The research locus was in Sade Traditional Village, Pujut District, Central Lombok Regency, NTB, using descriptive and evaluative analysis as a research method. The mass layout pattern of this Sade traditional house has a linear circulation with the facade of the Sasak traditional house oriented towards North-South. The orientation and pattern of this mass arrangement is a form of adaptation of contoured land, which is also responsive and contextual to the tropical natural environment because the building envelope will avoid excessive solar heat entering the space in the Bale. However, this Sade traditional house has an identity with a reasonably dense density between building masses with a building coverage of up to 70%. This causes natural lighting in the Bale (residential house) to be less than optimal.

Figure 2. Configuration of The Building Mass Arrangement at the Sade Traditional House
Source: Pramitasari *et al*. (2021)

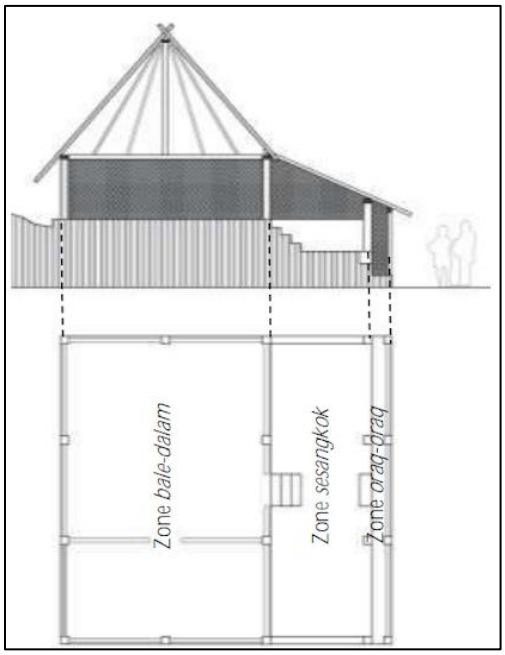

Figure 3. Bale Tani as Most House Typologies Adapts to the Contours
Source: Susilo (2019)

The building in Sade Village has a distinctive feature, namely the use of natural materials such as roofing material using thatch, wall material in the form of woven bamboo, bricks, wood, and clay walls mixed with cow manure to function optimally as thermal insulation in Bale Tani, Bale Bontar, and Bale Kodong residential buildings. The floor of the building uses clay materials mixed with rice husks.

Figure 4. Natural Air Conditioner in Bale Tani
Source: Authors' Documentation, (2024)

One of the buildings around Bale Tani is Bale Dagang which functions as a selling area for Sade's signature products. These products are made by the local people themselves, such as woven fabrics, bracelets, bags, and so on. Apart from that, the Bale-Trade building also functions to show the process of making these crafts directly. This Bale Dagang has the form

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of a stilt house which has an open concept with the aim that air circulation between the bale-tani masses is more maintained. Each mass in the bale building is also a single building mass with a ratio of the length and width of the building of 1:1, and the building masses are not attached to one another. This is undoubtedly good for air circulation between masses in the Sade traditional village so that the humidity in the bale is better maintained.

Figure 5. Bale Dagang
Source: Authors' Documentation (2024)

The site's landscape is dominated by circulation areas in the form of clay for pedestrians and not much vegetation on the site, considering that the density of buildings is relatively high. Around the site, vegetation functions as a boundary area between villages. The drainage path on the site follows the contour from the highest to the lowest contour and is directly infiltrated into outer space in the form of green open spaces and infiltration wells. Each building's mass is also made higher than the ground level as a strategy to prevent rainwater runoff.

DISCUSSIONS

The pattern of site design development in the traditional village of Sade is exceptionally organised, with the mass of buildings parallel to the contours. The facilities accommodated in this tourist village have also accommodated public needs, including mosques, toilets, Bale Dagang, and visitor parking areas. The location of the exit and entry access to the Sade traditional village is made one door on the west side of the site for security reasons. The site's strategic location, close to the city centre and supported by proper infrastructure, makes it very easy for tourists to visit Sade's tourist village.

Therefore, the principles of tropical climate green architecture found in Sade Village can be formulated as follows:

A. Water Conservation and Quality

Water is one of the critical elements in human life that can be captured, stored, filtered and reused. Only about 6% of the water that humans use for drinking.

In the case study of vernacular buildings in Sade Village, water management utilises existing contoured land, as seen in the drainage path on the site. It flows following the contour from the highest to the lowest contour and is directly infiltrated into outer space through green

open spaces and infiltration wells. Each building's mass is also made higher than the ground level as a strategy to prevent rainwater runoff. With the application of natural water management in Sade Village, it is evident that the buildings in the settlement still have green architectural principles even though using traditional methods.

B. Energy and Environment

Energy and environment are explained in three discussions: air conditioning, lighting, and energy utilisation.

C. Air Conditioning

Air conditioning can affect a building, as explained by Mohammadabadi (2011) that using wind catchers and windmills can produce energy for the air conditioning of a building. The passive ventilation strategy is a solution because artificial air uses electrical energy (Ragheb, A., El-Shimy, H., and Ragheb, G., 2016).

In the case study of vernacular buildings in Sade Village, it can be seen that the residential buildings still use natural air conditioning and do not use artificial air, such as mechanical air conditioners. Judging from the shape of the building mass in the form of a single mass, the ratio of the length and width of the building is 1:1 and the distance between building masses that are not attached to each other make the flow of air circulation between masses in Sade village efficient so that humidity inside Bale is better maintained.

D. Lighting

Most of the hot and dry areas of the world are located on the equator, with proper sunlight absorbed from the east and west sides of buildings, and sunlight can be observed on the north and south walls. The main goal of orientation in an equatorial climate is to maximise wind entry to reduce the daily temperature inside the building. The most optimal orientation applied in equatorial architecture is north-south.

In the case of the Sade traditional settlement, the mass layout pattern has a linear circulation with the facades of the Sade traditional houses facing north-south. The Sade traditional house has an identity with a reasonably dense density between building masses with a building coverage of up to 70%. This causes natural lighting in the bale (residential house) to be less than optimal.

E. Energy Utilization

The use of clean, renewable energy sources is one of the crucial factors in minimising the causes of global warming. Using alternative energy such as sunlight, wind, water, geothermal, and biomass have abundant and renewable energy sources.

Like traditional villages in Indonesia, Sade Village uses much energy from nature in daily life, such as using sunlight to dry food and laundry.

F. Conservation of Local Material and Resources

Natural buildings have various building systems and materials that emphasise sustainability because they rely on human labour rather than technology. This method aims to reduce the environmental impact of buildings and other support systems without compromising comfort or health. To realise sustainable buildings, natural buildings use natural materials that are still abundant, renewable, and can be reused or recycled.

The roofing material for the Sade traditional house uses local materials in the form of thatch for the roof, and the wall materials use woven bamboo, bricks, wood, and clay walls mixed with

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cow manure to function optimally as thermal insulation in Bale Tani, Bale Bontar, and Bale Kodong. Building elements such as roofs and walls use woven bamboo materials as barriers between spaces. In addition, the tenuous walls of woven bamboo also function like porous walls, which are suitable for air circulation (ventilation). The foundation of the bale-tani building functions as a platform for the nine pillars and is also known as siwaq tekan. This pole is made of logs called tekan. Above the tekan there is a rectangular wooden plate called an ampak. Ampak is connected directly to the support of the ribs called lampen and langkar, and functions as a link between structural systems. Besides functioning as a pillar holder, the foundation also functions as the room's floor and stairs. The material used as the foundation is clay mixed with cow manure and water, which is used as a strong adhesive. The foundation is made in layers, so it has high resistance.

CONCLUSION

The principles of green architecture can be found in the Sade traditional village, which still exists today. This can be indicated by the design and construction of compact, systematic, and regular building masses parallel to the contours with a linear circulation pattern; orientation of the building facing North-South of the site to optimise the design of passive lighting and ventilation of the building; regulation of building height and utilisation of roof and wall insulation materials from local materials with natural material characteristics that are light and hollow, responsive to natural conditions, humid tropical climate, and earthquake resistant; optimum provision of green open space to reduce the urban heat island effect; as well as provision of site utility systems responsive to the natural environment and resources. The principle of green architecture that exists in the traditional village of Sade needs to be maintained and improved for a better future for the sustainability of the ecosystem in the settlements of Sade Village.

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