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Architecture design and construction using bamboo case study: Buluh Awar village, Indonesia

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Abstract

Bamboo is a plant that can be used as a sustainable material for buildings. Bamboo is used as scaffolding and the main structure of the building. The advantages of bamboo as a building material include environmental friendliness, renewable, easy to cultivate, durability and low cost. This study aims to produce building design concepts with renewable materials in an effort to conserve bamboo. The method in this research is qualitative by using case studies. The focus of the research includes environmental conservation, architecture, construction and bamboo cultivation. The KAKR Bamboo Hall is a multifunction building as an addition for the children and teenagers' Sunday School in the historical Buluh Awar village. This multi-functional bamboo hall was originally designed and completed from 2019 to 2022, to educate the public about its benefits for environmental issues. This research seeks to preserve the environment by utilizing bamboo as building material. Utilization of bamboo supports environmental conservation. Bamboo is an important element for increasing the local community's economic level, makes the building in harmony with the environment/landscape; become a symbol of mutual cooperation and resistance to the burning and deforestation issues that are still rife as well as providing accommodation and attractions for nature-based tourism. At the architectural stage, preliminary design and design is carried out. The community is also involved in the construction phase which is based on community empowerment, namely the preservation, craftsmanship and handicraft stages. The use of bamboo as material and easy to cultivate as part of conservation efforts and provision of reserves for future needs. Buluh Awar Village is one of the bamboo-producing villages and a role model for using green materials in buildings. Every region can apply green materials to buildings according to their uniqueness.

Keywords Bamboo, environmental conservation, architecture, construction, bamboo cultivation

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1. Introduction

Bamboo can be used for various forms, for example furniture, panels, partitions, roofs, shapes and structures. Apart from that, bamboo is also used as food by both humans and animals. Based on Lapiran and Zakieva (2021), bamboo has the potential to be a building material for construction and architecture. The advantages of bamboo include its environmental friendliness, affordability, durability, resistance to seismic activity and high temperature resistance. Designs made from bamboo are easier to shape architecturally. Bamboo can be used as a building structure to replace materials such as steel and reinforced concrete. Bamboo material is good for earthquake vibrations, stiff and elastic at the same time. This makes bamboo an ideal material for construction.

Bamboo building materials can be found in various parts of the world. Traditional buildings have widely used bamboo materials as a response to the local climate. In India, several buildings have used bamboo material and applied it to floor plates, roofs, doors and windows.

The new design with bamboo structure can withstand fiber stress and bending stress toughness under static wind load. Natural bamboo is superior to scrider bamboo in terms of resistance and bending capacity. Bamboo has nonhomogeneous and anisotropic properties and varies in size. Climber bamboo has high dimensional stability compared to raw bamboo, so it is more suitable for construction. Natural bamboo on the other hand, the material performs better than crimber bamboo for new designs. Bamboo stems tend to bend more easily than natural bamboo. This may be due to their shape and relatively high stiffness.

According to Mimendi et al. (2022), Bamboo is a required structural element, one of which is in the construction sector. Bamboo stems can be used as structural elements, but only in small portions because they are round. Bamboo stems are produced naturally, unlike anthropogenic construction which relies on industrial manufacturing. The use of digital tools to enable the bamboo measurement process was found to be more efficient than conventional methods.

Digitalization of bamboo culms can provide information and shape, design efficiency, quality control, sustainability and structural behavior of bamboo. Design efficiency is able to minimize construction waste and optimize the structure so that sustainability can be achieved.

1.1. Different Parts of Bamboo and General Uses

The bamboo plant is typically divided into six parts; top, upper middle, lower middle, base, shoots, and leaves. Figure 4 shows some examples to the uses of different parts of a bamboo plant. Each part has uses in industries such as textiles, paper, construction, furniture, food and agriculture.

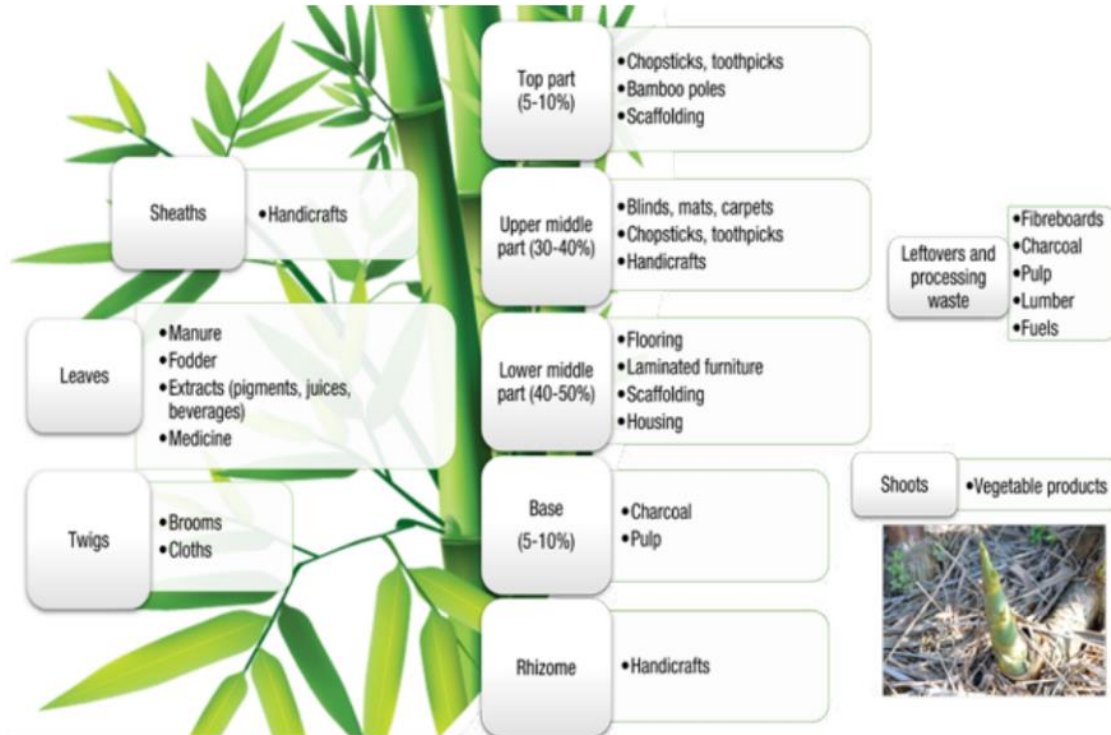


Figure 1. The bamboo plant: Different parts, different uses
(Source: Adapted by the author from Zhaohua and Wei (2018))

1.2. Environmental Conservation

Communities with middle to lower social and economic conditions usually use bamboo as their house material. This is due to low material costs. The raw material in the form of raw bamboo is easy to obtain. However, along with technological developments, the use of bamboo materials has varied. Even buildings for commercial purposes have been built using bamboo materials. The public should be given education on how to use bamboo and cultivate bamboo plants.

1.3. Architecture

Currently, bamboo buildings have become a trend both in Indonesia and the world. Several organizations have been concerned about developing bamboo as a building material, and some have been produced by industry. Technological development in bamboo continues to develop today.

1.4. Construction

Traditional architecture uses bamboo construction and is still used today. The use of bamboo for construction has been carried out in various types of buildings.

1.5. Bamboo Architecture in Indonesia

Bamboo is a common building material in Indonesia, seen in schools and resorts. Green School Bali, founded by John and Cynthia Hardy in (2008), is an international Pre-K to Grade 12 School located in the Bali jungle. It has 500 students from 41 nationalities and no government funding involved. The school offers full scholarships to 42 Balinese scholars and an additional 470 Balinese students participate in the 'Trash for Class' program through Green School's 'Kul Kul Connection' community integration initiative. Green School's mission is to create a sustainable world through a community of learners. It's not just a school but a hub for various social enterprises, including an innovation space and a resource management center called Kembali. The campus features unique wall-less bamboo classrooms designed to promote play, creativity, collaboration, and learning in Green School Bali.



Figure 2. Green School Bali

The bamboo bridge was the pioneering structure in the Orangutan Haven project, Deli Serdang, near Medan, Indonesia, serving as a model to promote bamboo use and educate locals on its versatile applications and construction methods.



Figure 3. The Bamboo Bridge OUH

The building, located in front of the iconic Haven Bridge at the Orangutan Haven site, features an A-shaped profile inspired by the nearby bridge and Karo architecture. The

roof's lower part has an organic shape reminiscent of taro leaves, serving as rain protection, aligning with the building's secondary function as a rain shelter.



Figure 4. The Orangutan Ticketing office

2. Materials and Methods

This research using qualitative methods with case studies. This research focuses on environmental conservation, architecture, construction and bamboo cultivation. The object of the research is KAKR Bamboo Hall that functioned as children and teenagers' Sunday School in the historical Buluh Awar village. The building was designed using bamboo material originating from the village. The use of bamboo in buildings as a material and construction process is explained in detail in the case study. Environmental conservation consists of outreach about bamboo conservation to the community, bamboo utilization and the preservation process. Then in the architecture section, consisting of preliminary design and building design. Preliminary design consists of design socialization, design ideas, making mockups and workshops. The building design consists of detailed engineering design and animation design. Construction consists of training and implementation. Bamboo cultivation is an effort to preserve bamboo material sources that involves community participation.

4. Result and discussion

4.1. The Context of Buluh Awar Village

Buluh Awar village is located in Sibolangit, North Sumatra, Indonesia, with a population of approximately 500 residents. The KAKR Bamboo Hall is part of a grand design for revitalizing the historical ground zero of a local church in Buluh Awar Village. Buluh is a Karonese term for bambu in Indonesian or bamboo in English, while Awar derives from Awaren in Karonese, which means hole on its nodes and allows water to flow naturally for households' usage. Bamboo grows naturally in the vast quantity and quality

surrounding this village. The village was part of a historical salt and trade route carried out by Perlanja Sira, salt bearers walking by feet during the pre-Dutch Colonialism era.

4.2. Environmental Conservation

Fast forward to the modern era, the village is becoming less developed. No more trade glory. The bamboo material is scarcely used in Buluh Awar and even burnt to provide vast land for productive crops such as paddy, brown sugar, and durians. Bamboo plants are considered pests, poor man's timbers and not strong as construction material. Things got worse due to massive illegal logging and deforestation which eventually caused a huge landslide in November 2021. The landslide size is approximately 80 meters long, 60 meters wide and 30 meters deep. It was so disastrous that sunk several houses and casualties cut off the main road entering the village. The villagers had to improve other roads as an alternative solution. Subsequently, the urgency to optimize the bamboo material is inevitable. Prior to that, public awareness and focus group discussion with the community were simultaneously carried out. The architect also urged the construction committee as the community representatives to visit bamboo buildings and tourism villages in Bali Island to collect insight so that the community shall accept the bamboo concept offered. The community was expected to learn how to preserve, utilize, and cultivate bamboo.



Figure 5. Landslide Disaster in Buluh Awar Village

4.3. Architecture

4.3.1. Preliminary design

The architect team conducted outreach in order to introduce the bamboo construction to the villagers of Buluh Awar. Approximately 150 local residents actively participated in this informative session. (Figure 6). Outreach is carried out so that the public understands the use of bamboo in design, from the preservation and planning to the construction stages.

Afterwards, design ideas developing design, including zoning the site, determining the shape of the building mass and building orientation. Macro concepts start from seed – baptism – children – teen – adults in faith. The roof geometry of traditional Karo houses is used as the main mass form. The geometry is arranged to resemble the formation of children and the people supporting each other as a symbol for community collaboration, in which the community are involved in the training, construction and cultivation phase. The construction process uses community empowerment methods to create a sense of mutual cooperation and ownership of the building. (Figure 7, 8, 9 and 10). Design models and maquettes were created to display design ideas in more detail, especially the use of bamboo in architectural design and construction (Figure 11). Then, a workshop was held to explain the design ideas to the community who would take part in the development process (Figure 12).



Figure 6. Outreach to the Buluh Awar Village Community

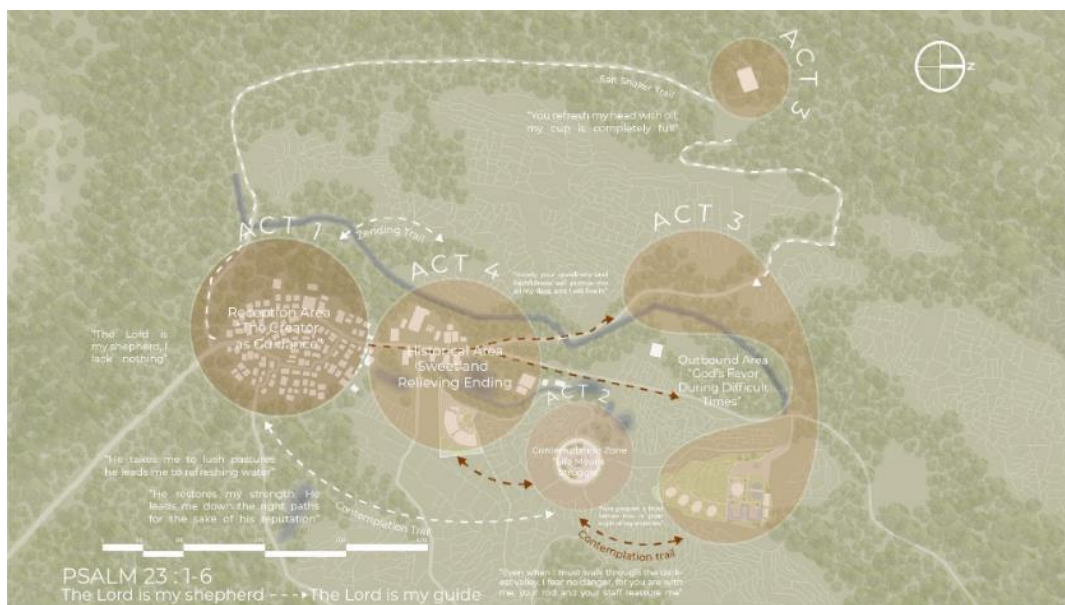


Figure 7. Grand Design



Figure 8. Masterplan of Buluh Awar Village

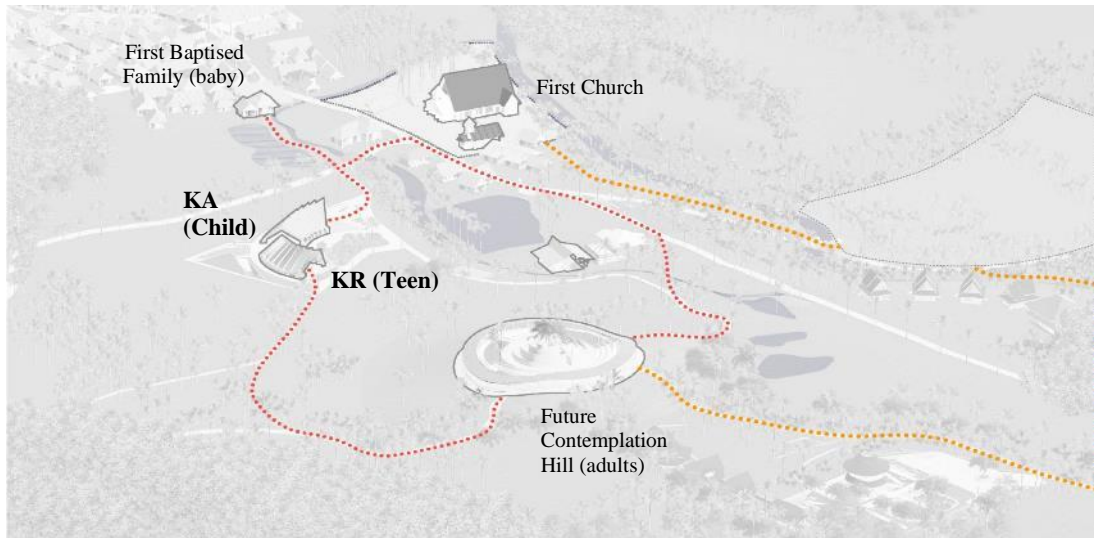


Figure 9. Macro Concept

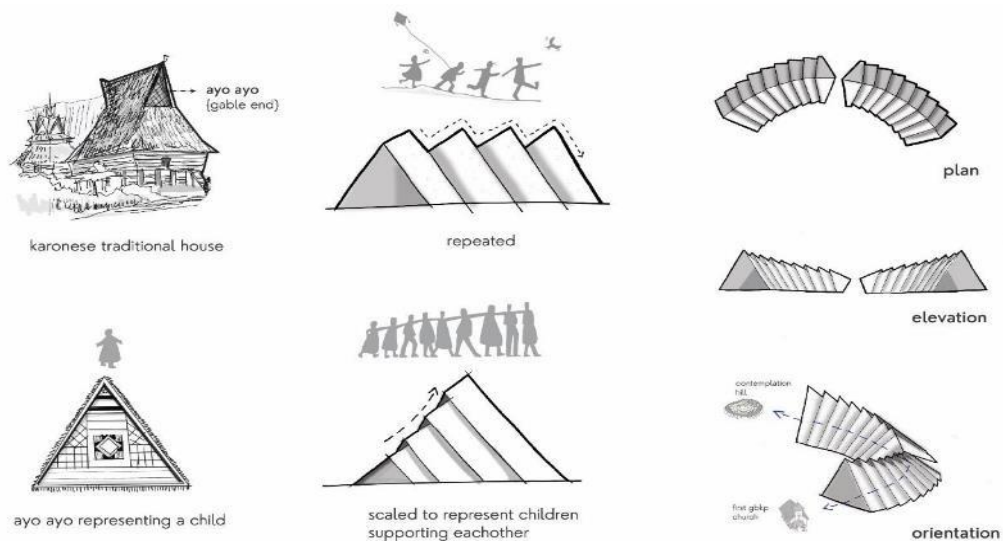


Figure 10. Micro Concept

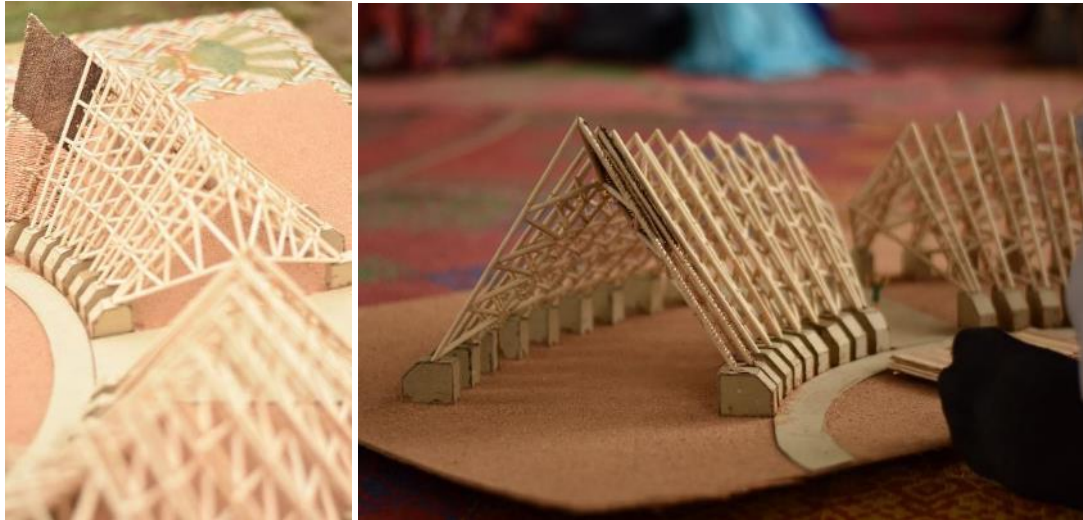


Figure 11. Maquette Study



Figure 12. Bamboo workshop

4.3.2. Design

Detailed engineering design (DED) is used for the purposes of the construction process (Figure 13-17). The DED drawing consists of architectural DED, structural DED and mechanical and electrical DED. Designs in 3-dimensional form and animations are created to make it easier for architects and engineers to understand the design to continue with the construction process.

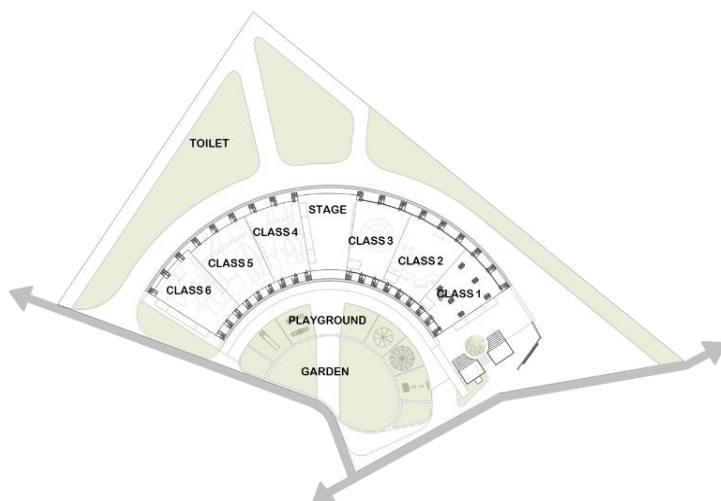


Figure 13. Groundplan

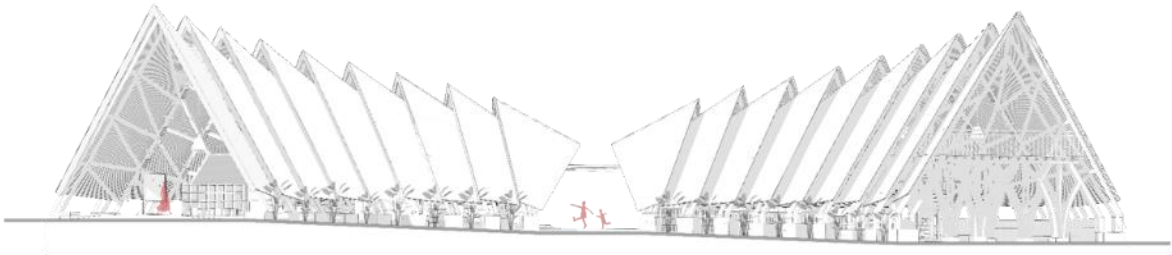


Figure 14. Front Elevation of KAKR



Figure 15. Side Elevation of KAKR

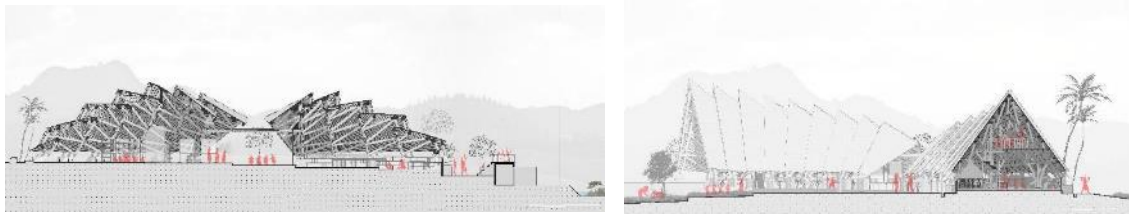


Figure 16. Section of KAKR

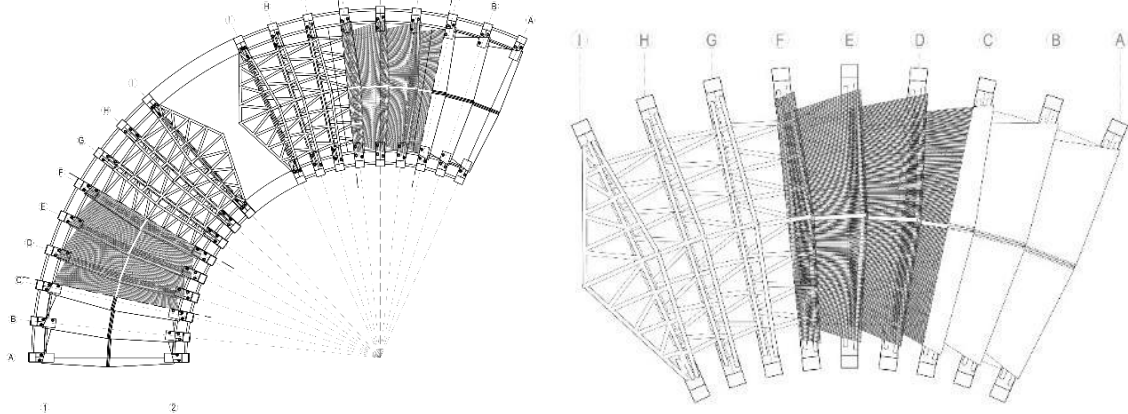
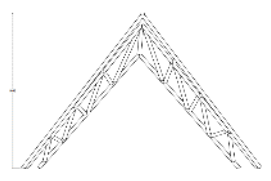


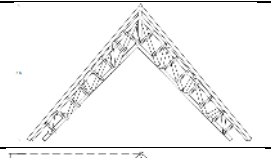
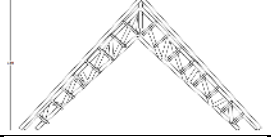
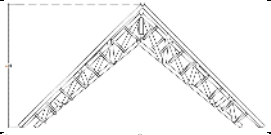
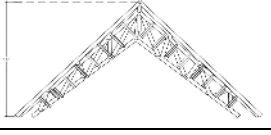
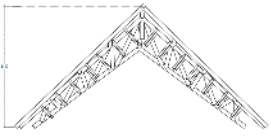
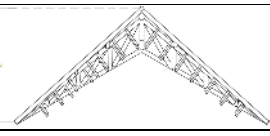


Figure 17. Truss Plan of KAKR

The roof structure is designed in several shapes, using various angles and heights (Table 1). The amount of bamboo used in construction, ie *Dendrocalamus asper* for structure 246 pcs (10 meters), *Gigantochloa apus* for supporting 463 pcs (10 meters), *Gigantochloa apus* for roof batten 230 pcs (6 meters), and *Gigantochloa apus* for roof shingles 1500 pcs (6 meters).

Table 1. Bamboo Truss Detail

No.	Bamboo Truss	Angle (°)	Height (m)	Image
1.	A	55,66	9	
2.	B	53,07	8,5	
3.	C	51,35	8	
4.	D	49,40	7,5	
5.	E	47,25	7	
6.	F	44,91	6,5	
7.	G	42,34	6	
8.	H	39,56	5,5	
9.	I	36,59	5	

4.3.3. Construction

4.3.3.1. Community Training

The training prior to the construction is a very essential phase to carry out regarding bamboo materials. The architect team urges the involvement of the community instead of engaging the Contractors. The bamboo hall should become the tool of training for the community, in which the community was directly involved in the training process. This training process empowers village communities to be directly involved in the KAKR building construction process. The training is so essential so that the community will have

the capacity to carry out future maintenance as well for the bamboo hall. (Figure 18). The initial training carried out is the training of bamboo preservation in order to enhance the bamboo durability against termite and fungus. Moreover, sufficient roofing and pedestal base for bamboo structure shall be undertaken. (Figure 19).



Figure 18. Community Training



Figure 19. Three methods to enhance the bamboo durability

A high skilled labor from Probolinggo, Java Island, who was trained in the previous bamboo bridge in Orang Utan Haven, was invited to Buluh Awar village to train the villagers for three months during the construction of treatment shelter and part of the community hall. After the transfer of knowledge was carried out, the high skilled labor returned back to Java and the local community continued the hall until its completion. As the result, approximately 100 villagers participated in whole community training, including women and elderly people. Their involvement enhanced their skills and positively impacted the local income. This community training is a proactive step to strengthen skills and provide economic opportunities for the residents, aligning with their active engagement throughout the project planning process. This process will continue with constructing future villas and a café in Buluh Awar Village according the Grand Design.

4.3.3.2. Implementation

Construction implementation was carried out with community empowerment approach. The architect team continues the training method with the community by building the hall

the tool for training. Approximately 15 local villagers participated directly in this construction training. (Figure 20).



Figure 20. Initial Stage of Construction

The mentoring and construction process of this building took approximately two years. The structure evolved into a tangible representation of sustainable design concepts, utilizing bamboo as primary construction material. Architecturally, KAKR Hall seamlessly integrates the unique bamboo structure with a design that reflects aesthetic beauty and environmental sustainability. The construction process actively involved the community, reinforcing communal bonds and fostering economic empowerment. (Figure 21).



Figure 21. The Final Outcome of the KAKR Bamboo Hall

4.3.3.3. Bamboo Cultivation

Bamboo cultivation is the ultimate training phase to ensure the sustainability of bamboo material. Bamboo is a versatile, strong, renewable as well as environment-friendly material that can be easily grown for various purposes. Bamboo is also considered the fastest growing woody plant on earth. Bamboo cultivation is relatively fast and does not require particular maintenance time. Preparation for bamboo cultivation, from seeding,

nursery, and planting until ready to harvest. The bamboo requires 5-7 years to grow before harvesting for various purposes. (Figure 22). This training of bamboo regeneration will be planned as a cycle of activities to ensure future reserves, for environment protection, for education, community empowerment, and to decrease wealth and gender inequality.



Figure 22. Bamboo Regeneration

4.3.4. Impact

The local villagers build their awareness to support the Tourism in Buluh Awar village as well as the awareness to preserve the environment. There are approximately 10-20% increasing numbers of visitors coming to Buluh Awar Village after the completion of KAKR Hall (Children's Service Youth Service Hall). In 2022 there will be 6.368 visitors and in 2023 until August there will be 4.055 visitors and it is estimated that there will be 10.000 visitors until the end of the year. The multifunction bamboo hall was built as a trigger to transform the image of local people from bamboo burners to bamboo preservers.



Figure 23. Social and Culture Events



Figure 24. The condition and functionality of the KAKR building

The increasing of number of visitors was due to assistance of the Deli Serdang local regency to rebuild the road cut off by the landslide disaster. The local regency saw the importance of the KAKR Building as trigger for the new tourism spot and this road was really important as the main access for the visitors to visit Buluh Awar village.



Figure 25. The impact of road reconstruction

The long-term impact of the KAKR building in Buluh Awar encompasses crucial aspects. Firstly, its presence enhances tourism in the area, fostering additional income and local business opportunities. Secondly, community involvement in the building's construction and maintenance leads to sustained economic empowerment. Thirdly, using bamboo as a construction material positively contributes to environmental conservation, establishing a model for sustainable development. Fourthly, there is an increase in public awareness and education regarding the benefits of bamboo, resulting in long-term positive effects on sustainable practices within the community. Consequently, KAKR Buluh Awar serves as a local symbol and provides a sustained, positive contribution to the community and the environment. This is also reflected in the expansion projection to the surrounding villages, including nearest Sibolangit Village, involving approximately 100 individuals in this initiative. The projection of 5000 - 10.000 people for future training program according the Time Frame in the Grand Design, including the local architecture students and academia that gradually visited Buluh Awar village for bamboo learning.



Figure 27. Craftsmanship

5. Conclusion

Bamboo, which was initially considered a pest, turns out to have high value as a sustainable material. Currently bamboo has been used for various types of building functions. Bamboo is a sustainable material that can be used for building design. It is environmentally friendly, renewable, easy to cultivate, durable, and cost-effective. The use of bamboo in construction can contribute to environmental conservation efforts and promote sustainable architecture. The paper also highlights the importance of community involvement and education in bamboo cultivation and construction. The KAKR Bamboo Hall in Buluh Awar village serves as a successful case study in promoting the use of bamboo as a sustainable building material.

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Conflict of Interest

The authors declare there is no conflict of interest

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