

‘Resilience in Bamboo’

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ABSTRACT: A number of zero-carbon prefabricated bamboo buildings were built engaging marginalized communities in a few places in South Asia. This action-research was conducted by teachers and students of architecture who designed and built sustainable structures made of local materials such as bamboo, straw, rope and mud. The prototype design was revised, whenever needed, according to the climate, topography, landscape, materials as well as the traditional wisdom of the local tropical context. The building is significantly cost effective, especially in rural areas since it uses indigenous materials and local labor. The prototype structure using treated bamboo and a special rope-knotting system originally went through shaking table and wind tunnel tests by the prototype designer. The multi-use structures, now a year old, are weathering quite well. Short-term temperature readings of outdoor and indoor of some of these structures were collected to study the thermal performance in summer, and the indoors were found to be more comfortable than the outdoors.

The fact that most of the participants are women in both the students and community members prove the ability and confidence of women in building industry, which also addresses sustainable development goals.

The prefabricated bamboo structures have been particularly impactful in disaster-prone areas, serving as disaster rehabilitation buildings. After a devastating flood, over 2,000 of these buildings were constructed in a city, showcasing their value in disaster resilience. The project also allowed students and academics to directly apply classroom knowledge through hands-on building experiences.

The paper thus focuses on the major contributions of this action-research on constructing sustainable buildings addressing climate change, disaster resilience, involvement of marginalized communities especially women, and the knowledge dissemination in the academia.

KEYWORDS: sustainability, zero-carbon building, community participation, disaster rehabilitation building

INTRODUCTION

Traditional architecture ensures new changes and adopts well being for the dwellers through understanding of the environment and the human responsive systems (Doza and Ema 2019). In recent years, the global discourse on sustainable architecture has made an important shift towards innovative and eco-friendly solutions that address both environmental challenges and social inequities (Asefi and Afzali 2016). Against this backdrop, a transformative initiative was tried in various regions of South Asia, where a series of zero-carbon prefabricated bamboo buildings were constructed. This action-research endeavor, led by a group of dedicated academics, sought to engage marginalized communities, revolutionize sustainable construction practices, and contribute to broader societal goals.



Figure 1: Bamboo in Resilience. Source: (Ryan 2023)

1.0 BACKGROUND

1.1 Overview of the zero-carbon prefabricated bamboo buildings

The zero-carbon prefabricated bamboo buildings are examples of resilience, embodying a transformative approach to sustainable construction in the face of environmental challenges (Surma (Salma 2022)). Rooted in resilience, these structures leverage bamboo, straw, rope, and mud to create easily adaptable buildings. The design and the materials and methods of construction along with the learning from the traditional wisdom, make the buildings withstand the demands of various contexts. This adaptability also reinforces their capacity to serve diverse communities. The innovative structural elements, including treated bamboo and specialized rope-knotting system are the two important aspects of the resilience of the building. Rigorous testing of the prototype through shaking table and wind tunnel experiments ensured their durability and ability to withstand disasters to a great extent, contributing to their stability in the face of potential challenges. This emphasis on structural integrity aligns with the broader concept of resilience, creating buildings that can endure unforeseen circumstances and stand as symbols of sustainable longevity (Ben-Alon 2020). In disaster-prone regions, these prefabricated bamboo buildings emerge as resilient solutions with their modular and prefabricated design. Made of easily transportable bamboo panels, they facilitate swift assembly, enabling rapid response in the aftermath of natural disasters. The scalability of these structures has been demonstrated in the construction of thousands of buildings following devastating floods, showcasing their immediate applicability in crisis situations and underscoring their vital role in disaster resilience (Vengala and Raghunath 2020). In the aftermath of devastating monsoon rains and flooding in Pakistan, architect Yasmeen Lari led a humanitarian response to provide relief to the affected communities. Teaming up with INTBAU Pakistan and the Heritage Foundation, Lari initiated the construction of 1,000 prefabricated emergency shelters in severely impacted regions. These shelters, based on Lari's design known as the Lari Octa Green (LOG), were originally conceived after the 2015 Hindu Kush earthquake. Initially serving as emergency relief, some shelters now integrate adobe wall insulation, transitioning into a permanent housing solution for underserved communities in Sindh, addressing both immediate and long-term needs (Ahmed 2023). The commitment to resilience extends beyond the physical structures to encompass the empowerment of local communities. Through inclusive practices that actively involve women in teacher, student and community members, these projects address broader sustainability goals, fostering a sense of ownership and self-sufficiency within communities. A key goal of this action research was to empower women in marginalized communities in terms of building disaster rehabilitation buildings. The zero-carbon prefabricated bamboo buildings not only embody resilience in their design and construction but also contribute to the resilience and well-being of the communities they serve.

1.2. Engagement with marginalized communities

Engagement with marginalized communities expresses commitment to social equity and community empowerment. In various projects, such as the construction of zero-carbon prefabricated bamboo buildings, this engagement involves active collaboration among female members of the academia as well as marginalized communities. By placing an emphasis on inclusivity, the initiative ensures that the expertise of marginalized individuals are incorporated, fostering a sense of agency and community-driven development (Nurdiah and Anik 2020). Notably in this project, the deliberate inclusion of women in teacher, student and the local community breaks gender barriers, demonstrating the transformative impact of gender-inclusive practices. This engagement extends beyond the immediate project, promoting knowledge exchange and capacity building, creating a reciprocal learning environment. Ultimately, the engagement with marginalized communities serves as a catalyst for social change, economic empowerment, and the cultivation of sustainable, resilient communities.



Figure 2: Discussion and interactive session with community members. Source: (Authors 2023)

2.0 OBJECTIVE OF THE ACTION RESEARCH

The action research on zero-carbon prefabricated bamboo buildings is guided by a few objectives:

- Advancing Sustainable Construction Practices
- Empowering Marginalized Communities, Especially Women Members.
- Enhancing Disaster Resilience
- Knowledge Dissemination and Academic Integration

3.0 SUSTAINABLE BUILDING CONSTRUCTIONS: SITE AND LOCATION

The initiative was based on a zero-carbon bamboo building project of the Department of Architecture, SoAD, BRAC University Bangladesh, Heritage Foundation Pakistan, and The British Council UK under a gender grant of the British Council. A total of 25 institutions in Bangladesh, Pakistan, UK, Italy, USA and India took part. A 3-day workshop was held and screened live on various online platforms in several countries in early 2022 when the participants consisting of women students, graduates of architecture and women members of marginalized communities built the bamboo structures simultaneously in those countries. The selected volunteer students from Bangladesh and Pakistan later joined their British counterparts to build the bamboo structures in London and Bristol, UK in May 2022. The events thus showcased and encouraged women in the design and construction of prefabricated bamboo buildings which can be used as regular houses or a disaster rehabilitation structure. Among others, the following organizations were collaborated with the Bangladesh segment of the project:

Inside Bangladesh:

- Department of Architecture, School of Architecture and Design, BRAC University, Dhaka
- Department of Architecture, Leading University, Sylhet
- Architecture Department, Premier University, Chattogram
- CoCreation.Architects, Jhenaidah
- Institute of Architects Bangladesh, IAB.
- Paraa, Dhaka
- Shailan School, Dhamrai, Dhaka
- The Chakma Royal Family, Rangamati

Outside Bangladesh:

- The Department of Architecture and Planning, Indian Institute of Technology (IIT), Roorkee, Uttarakhand, India
- Department of Landscape Architecture, College of Agricultural Sciences and Natural Resources, Texas Tech University, Lubbock, Texas, USA
- The International Network for Traditional Building, Architecture & Urbanism (INTBAU), Pakistan & UK



Figure 3: Site & Location inside Bangladesh and outside of Bangladesh. Source: (Authors 2023)

3.0 METHODOLOGY

This action-research project involved the design and construction of zero-carbon prefabricated bamboo buildings in various rural areas of South Asia, engaging marginalized communities, particularly women. The methodology included collaborative efforts by architecture teachers and students who utilized local materials such as bamboo, straw, rope, and mud to build sustainable structures. Prototypes were rigorously tested and designs were adapted based on climate, topography, landscape, materials, and traditional wisdom. The project incorporated hands-on collaborative design talks and practical workshops to involve students and community members directly in the construction process. Short-term temperature readings were collected to assess thermal performance, and the structures were monitored over a year for durability. The prefabricated bamboo panels, designed for easy transport and assembly, were used effectively in disaster-prone areas for rehabilitation purposes, with over 2,000 buildings constructed post-flood. This research demonstrated the capability and confidence of women in the building industry and contributed to sustainable development goals, integrating practical knowledge into academic curricula and highlighting the role of sustainable architecture in disaster resilience and climate change mitigation.

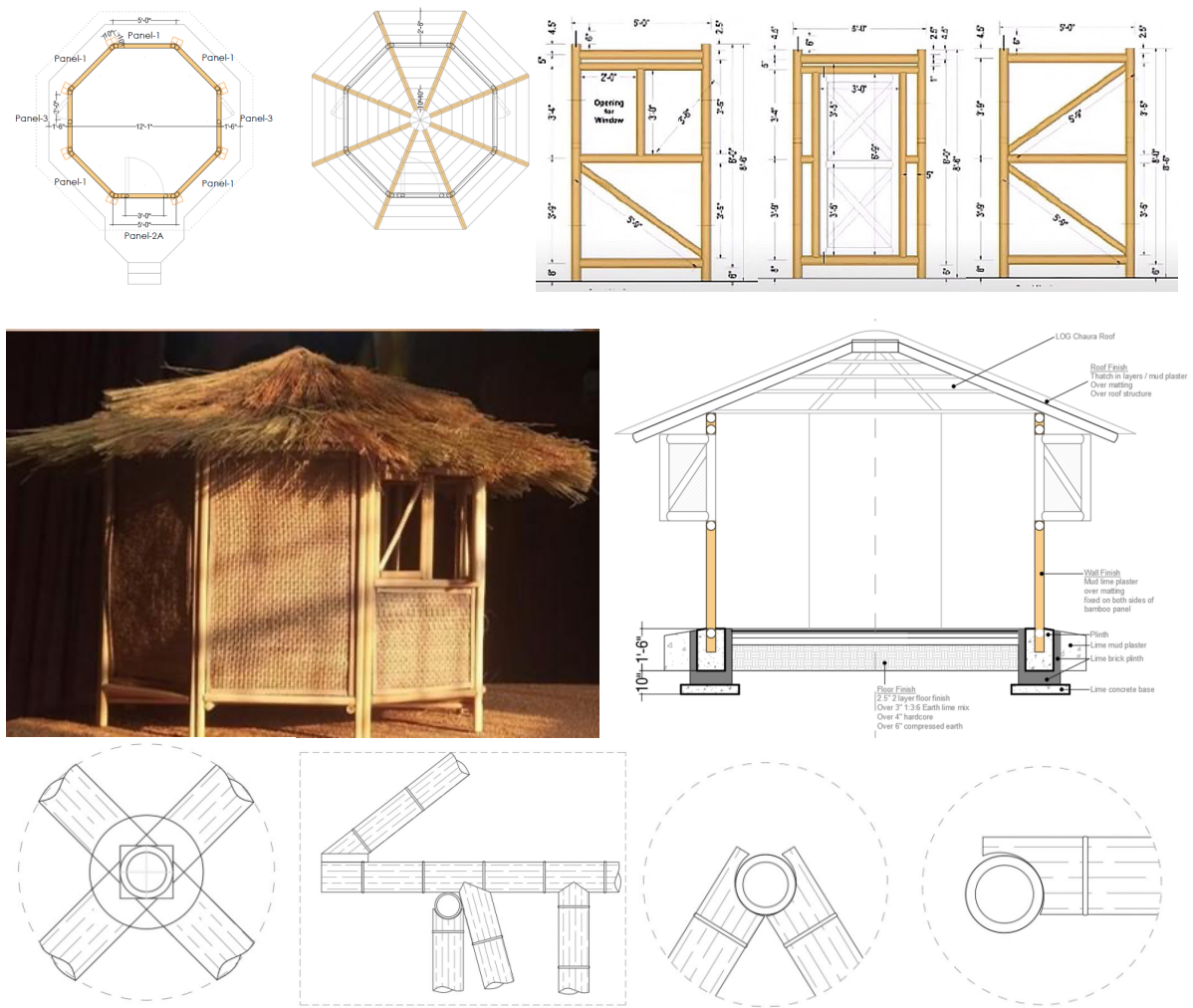


Figure 4: Plan, Elevation, Model, Section & Details of the prototype Zero Carbon Bamboo Building. Source: (Ahmed 2023 and Author 2022)



Figure 5: Workshop and bamboo treatment. Source: (Authors 2022)

4.0 COST EFFECTIVENESS AND SUSTAINABILITY

The zero-carbon prefabricated bamboo buildings showcase a blend of cost-effectiveness and sustainability, particularly in rural South Asian communities. The cost-effectiveness is rooted in the use of indigenous materials like bamboo, straw, rope, and mud, as well as the utilization of local labor. This not only reduces construction expenses but also stimulates local economies, aligning with sustainable development goals. The involvement of academics, students, and community members in the design and construction phases adds value by combining traditional wisdom with modern architectural insights, optimizing cost efficiency.



Figure 6: Zero carbon bamboo building construction. Source: (Authors 2022)

5.0 THERMAL PERFORMANCE AND COMFORT

The thermal performance and comfort levels of the zero-carbon prefabricated bamboo buildings are critical aspects that contribute to their overall sustainability and suitability for the local climate. The buildings, constructed with a focus on utilizing indigenous materials like bamboo, straw, rope, and mud, undergo a design adaptation befitting to the varying climate, topography, and landscape of the tropical context. Short-term temperature readings collected from both outdoor and indoor spaces of a few structures in the warm-humid Bangladesh reveal a noteworthy aspect - the indoors are found to be more comfortable than the outdoors, indicating a positive impact on occupant comfort. This finding underscores the success of the design in creating living spaces that are thermally comfortable, likely attributed to the choice of materials and the appropriate design revisions based on local conditions and expertise.

The use of treated bamboo, straw roof with extended eaves for sun and rain protection, mud floors, mat walls and awning windows allowing ventilation contribute to the positive thermal performance of the buildings. These features keep the indoor temperatures lower than outdoor temperatures. The buildings' ability to provide a comfortable indoor environment in the challenging tropical climate shows the effectiveness of the design strategies employed. And these zero carbon buildings are big energy savers. This emphasis on positive thermal performance enhances the livability of these structures, and also aligns with broader sustainability goals. By creating indoor spaces that are more comfortable than the outdoor environment, the buildings reduce the reliance on external cooling systems, contributing to energy efficiency and environmental conservation.

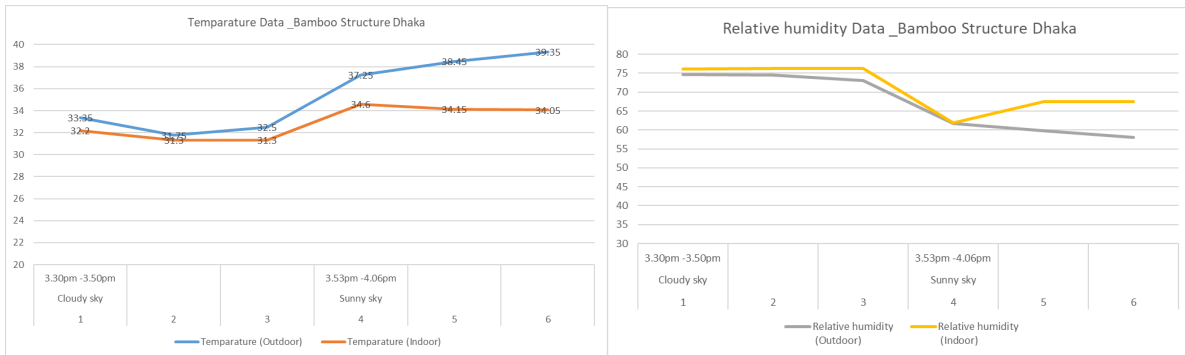


Figure 7: Thermal performance and comfort of the zero-carbon prefabricated bamboo building Dhaka. Source: (Authors 2023)

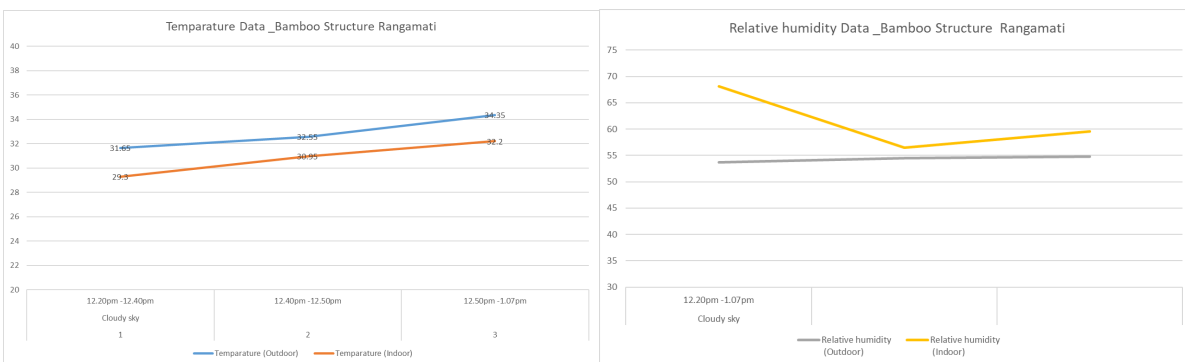


Figure 8: Thermal performance and comfort of the zero-carbon prefabricated bamboo building Rangamati. Source: (Authors 2023)

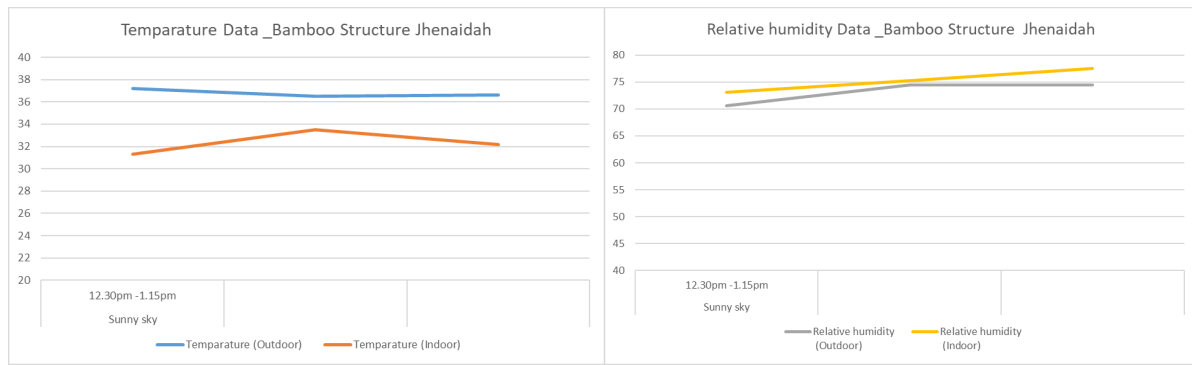


Figure 9: Thermal performance and comfort of the zero-carbon prefabricated bamboo building Jhenaidah. Source: (Authors 2023)

In summary, the thermal performance of the zero-carbon prefabricated bamboo buildings resulting in better comfort indoors that are shown in these charts add to their success. The integration of sustainable materials, careful design considerations, and the adaptability to local conditions collectively contribute to creating living spaces that are not only environmentally conscious but also prioritize the well-being and comfort of their occupants.

6.0 EMPOWERING WOMEN IN THE BUILDING INDUSTRY

The involvement of women in the construction of zero carbon bamboo buildings represents a significant stride towards gender empowerment and equality. The fact that most participants, both among students and community members, are women is a powerful evidence of their ability and confidence in the building sector. This engagement not only breaks traditional gender norms but also addresses broader sustainable development goals by promoting inclusivity and diversity within the industry. Empowering women in the building industry involves providing them with opportunities for skill development, hands-on experience, and leadership roles. In the context of the zero-carbon prefabricated bamboo buildings, women actively participated in designing and constructing sustainable structures using local materials such as bamboo, straw, rope, and mud. This hands-on involvement not only imparts practical skills but also instills a sense of confidence and ownership in women, challenging stereotypes about their roles in traditionally male-dominated fields.



Figure 10: Women in the construction of zero carbon bamboo building. Source: (Author 2023)

Moreover, the engagement of women in the construction process goes beyond the immediate project, contributing to their economic empowerment. By participating in the creation of sustainable buildings, women become active contributors to their communities' development, fostering a sense of self-sufficiency and independence.

The impact of this endeavor extends to the broader narrative of gender equality, demonstrating that women, especially of the marginalized communities, can excel in technical and hands-on professions. This not only transforms perceptions within the local communities but also serves as a model for sustainable development initiatives globally, highlighting the importance of gender inclusivity in various sectors.

7.0 DISASTER RESILIENCE



Figure 11: Zero carbon prefabricated bamboo buildings. Source: (Author 2023)

This building so far has been constructed in many places of South Asia. A great example of this is the building of about 2000 such rehabilitation homes in areas in Pakistan that were devastated by recent floods. As mentioned earlier, the prefabrication of panels made it easier to make the panels in a safe place and then transporting those to the flood affected areas where the buildings were erected at a great speed. In this way it was possible to build a large number of houses in the affected areas in a short time. It has been also seen that well-treated bamboo can withstand floods and heavy downpours. Also, the raised plinths are giving protection against flooding.

8.0 ACADEMIC IMPACT

The zero carbon prefabricated bamboo building's contribution to knowledge dissemination, hands-on learning, and the integration of practical insights into academic settings is noteworthy. The engagement of academics and students in the action-research project creates a dynamic bridge between theory and real-world application.

The involvement of teachers and students of architecture in designing and constructing sustainable structures using local materials such as bamboo, straw, rope, and mud is a hands-on learning experience that enriches academia. This practical engagement not only imparts valuable skills but also fosters a holistic approach to education by integrating traditional wisdom with modern architectural insights. The direct input of knowledge gained through hands-on construction in classrooms enhances the academic curriculum. The experiences from the project become a valuable source of real-world examples, case studies, and best practices. This direct transfer of knowledge ensures that academic institutions stay current with sustainable construction practices and align their teachings with practical industry applications. Furthermore, the academic impact extends beyond the immediate project, as insights gained from the action-research are likely to contribute to academic publications, research papers, and conference presentations. The collaboration between academics and the community creates a reciprocal learning environment where both parties benefit from each other's expertise and experiences. The participants also gain from the cultural understanding and enrichment.

In essence, the academic impact of the project lies in its ability to bridge the gap between theoretical knowledge and practical application. It promotes experiential learning, contributes to the enrichment of academic curricula, and ensures that academia plays a vital role in advancing sustainable building practices, climate change mitigation, and disaster resilience. The project's academic impact is a testament to the value of hands-on, community-engaged research in shaping the future of sustainable architecture and construction education.

CONCLUSION

In conclusion, the zero-carbon prefabricated bamboo building project stands as a beacon of innovation, sustainability, and community engagement. The multifaceted approach, involving academics, students, and marginalized communities, has yielded tangible benefits that extend beyond the immediate construction of sustainable structures. The success of the project lies in its ability to address key challenges such as climate change, disaster resilience, and gender inclusivity in the building industry. The cost-effective nature of the building, utilizing indigenous materials and local labor, not only makes them economically viable but also contributes to the economic empowerment of the communities involved. The thermal performance of the structures, demonstrated by short-term temperature readings, underscore their adaptability to local climates and their capability to enhance the well-being of occupants. The active participation of women, both among students and community members, challenges gender norms and fosters empowerment in the building industry. This inclusive model not only contributes to sustainable development goals but also serves as a testament to the ability and confidence of women in traditionally male-dominated fields. The disaster resilience of the specially designed prefabricated bamboo buildings, exemplified by their successful use as disaster rehabilitation structures, showcases their pivotal role in enhancing community resilience. The scalability, mobility, and durability of the structures make them invaluable assets in disaster-prone regions, providing swift and effective housing solutions. From an academic standpoint, the project's impact is evident in the hands-on learning experiences, knowledge dissemination, and the integration of practical insights into classrooms. The collaboration between academia and the community creates a synergistic learning environment that enriches both theoretical understanding and real-world application. The zero-carbon prefabricated bamboo building project represents a holistic and impactful approach to sustainable construction. Its contributions to economic development, gender empowerment, disaster resilience, and academic enrichment make it a model for sustainable development initiatives worldwide. It becomes evident that this action-research has not only constructed sustainable buildings but has also laid the foundation for resilient communities and a more inclusive, sustainable future.

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