



## Bamboo Dome: Tradition meets Digital Manufacturing

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### Abstract

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This study describes the design and construction process of a bamboo dome structure within the framework of an Indo-German international project. The design of the dome developed in collaboration with a group of students. Each student creates a design idea for each of the triangles on the dome with a specific design idea and connection details. The design aims to demonstrate how bamboo material can be designed using digital manufacturing techniques as well as constructed using traditional connection methods. The aim of the design build project is not only to construct a bamboo dome, but also to investigate how bamboo can be integrated with modern manufacturing techniques. In the design, specific connectors and surfaces are planned to be produced using digital fabrication tools that will be integrated into the dome design. Therefore, this research, aims to provide a model for sustainable and innovative building systems by investigating the integration of bamboo with digital fabrication.

**Keywords:** Bamboo; Dome; Digital Manufacturing; Sustainable Design.

### 1. Introduction

The use of sustainable materials has increased in recent years. The idea of creating a sustainable architectural structure or the idea of using sustainable materials in its design, is more satisfying to designers, practitioners and users. Bamboo is a grass variant that comes under the grass genre, hence is quick growing and can be grown in almost all climatic conditions in the tropical and temperate zones. Bamboo, which can be considered as a sustainable material, has a fast growth rate, flexibility, high strength to weight ratio and carbon sequestration potential (Liese & Köhl, 2015). For this reason, bamboo can be used as an alternative to traditional structural materials such as steel, concrete and wood. Traditionally used in local architecture in Asia, Latin America, and Africa, bamboo has opened up new avenues for integration into contemporary and experimental architecture through recent developments in digital production (De Souza, 2021). From temporary shelters resistant to climatic conditions to quick-to-assemble and easily disassembled clamp systems, bamboo stands out for its versatile applications. While bamboo materials are still designed using traditional methods, research and studies are also being conducted on digital fabrication methods to adapt bamboo to modern architecture.

This paper documents the design-build process of a bamboo dome structure realised as part of an Indo-German international collaborative project and explores the production of the traditional material using both traditional techniques and modern (digital fabrication) techniques. Digital fabrication of components also enables to 18 precision in measurements which is absolute essential for dome construction. This is an important parameter without which the dome structure gets not only distorted but also structurally weak. The building was designed and constructed in collaboration with architecture students in order to draw attention to sustainable building materials. The design was planned from the beginning by a group of students and professors in discussion. This planning process generated solutions for connectors, facade cladding and how to integrate them into the bamboo dome. Both traditional and

digital production methods were discussed and integrated work was planned. The main aim of this project is not only to build a bamboo dome, but also to emphasise how bamboo can be integrated with modern production techniques. In addition, it is to create a hybrid methodology that blends innovation and tradition. This work therefore contributes to a wider discourse on production experimentation, sustainable construction and educational design-build studios. By demonstrating how a local material can be reinterpreted with contemporary design insights, this study provides a model for similar projects where people from different disciplines and cultures can work together. Additionally, this process drew upon the simulation-based educational models of Bhat, Grunwald, and Hanke (2023) and the augmented reality-supported design-production approaches of Kawasaki and Grunwald (2023). Such digital methods enabled students to contribute more deeply to the project process and develop alternative solutions.

The paper is structured as follows: Section 1 presents a review of the existing literature on bamboo as an architectural material, the bamboo dome and the integration of bamboo with digital fabrication techniques. Section 2 summarises the methodology, including material sourcing, design drawings of the bamboo construction process, the digital design process and the two-stage construction strategy. Section 3 presents the results of the first implementation phase, focusing on the assembly of the bamboo dome, addressing technical challenges, student engagement and preliminary observations on material behaviour. Section 4 discusses the conclusions drawn from the study. This chapter also explore the wider implications of combining traditional manufacturing methods with digital design approaches. Finally, Section 5 concludes with reflections on the project's contribution to sustainable architecture and intercultural design education and offers recommendations for future research and practice.

### **1.1. Geodesic Bamboo Dome**

Geodesic domes are structural systems consisting of triangular elements in spherical or semi-spherical shapes. These triangles not only add a visual rhythm to the structure but also provide structural stability by ensuring that the loads are evenly distributed throughout the entire structure (Wikipedia, 2024). Thanks to these features, geodesic domes offer both a visually dynamic structure and highly efficient engineering solutions.

In this building system, it is preferred that each triangle used is as equilateral as possible. In this case, the loads are distributed more or less evenly across all the supporting elements, maximizing structural efficiency (Davis, 2011). It also reduced the number of parts required during manufacture and simplifies the assembly process. In this study, it was not to use equilateral triangles; the structure was designed using triangles of three different sizes based on the calculations performed. Thus, structural stability was achieved in a balanced manner.

Geodesic domes constructed from natural and sustainable materials make sense not only from an architectural and engineering perspective, but also from an environmental responsibility perspective. Environmentally friendly materials such as bamboo work in harmony with these systems, providing both lightness and durability. In addition, construction time is short and construction is easier than with other structures. In addition to all these, integrating digital fabrication into the design process can not only speed up the production phase, but also make the process more accessible and manageable.

### **1.2. Background and Context of Bamboo Architecture and Digital Fabrication**

Bamboo is a natural building material that is preferred in different regions of the world for different building types of buildings and is characterised by its sustainability. With its durable, economical and flexible structure, it has the potential for versatile use in both traditional and contemporary architectural applications. One of the main reasons why it is preferred especially in local architecture is its fast growth and high resistance to environmental impacts (Liese & Köhl, 2015). In recent years, the growing interest in sustainable materials and the search for formal diversity in architecture have enabled bamboo to find a place in modern architecture. However, the advantages of digital production techniques such as precision, time saving and reproducibility have also encouraged the integration of bamboo into digital fabrication processes. Today, bamboo, considered not only in its traditional context, but also in an integrated manner with parametric design and digital fabrication technologies, plays an important role in the future of sustainable building systems.

Digital fabrication is a method that can be integrated into architectural design processes at many different stages. It can be used in a wide range from the creation of the general form of the building to the determination of facade elements and even detail solutions. In this study, digital fabrication played an active role especially in the design process of connectors. Similar applications are found in the literature.

The connectors used in the study conducted by [Crolla et al.](#) in 2017 consist of eight different node types that bring together different numbers of elements, and each of them is specially produced using a 3D printer. The design process aimed to minimise the amount of support material used during printing, reducing both production time and material consumption. Each node is shaped according to the load it will carry and its position, and the holes required for mechanical connections such as screwing are also included in the design before production. The result is a connection system that is both structurally durable and efficient to manufacture.

The other project, the connector designed in the study by Kladeftira et al. at ETH Zurich was specially designed to be compatible with natural and irregular materials such as bamboo and called the ‘notch’ system. Manufactured using polyamide (PA12) material and MultiJet Fusion (MJF) method, this element provides high strength and reduces material waste. The notch design prevents fibre separation by evenly distributing loads across the bamboo. Each part can be parametrically modelled and adapted according to the angle differences at the connection points. Each node consists of the body, extensions, additional components and standard covers. Such studies point to the increasing use of digital fabrication in the architectural context in the literature. Today, the reasons for the preference of digital production techniques in the field of architecture include, in particular, the facilitation of the assembly process and the reduction of total costs. In addition, with parametric design and the integration of various software tools, more accurate calculations can be made, enabling the creation of designs with minimised error margins and high accuracy.

**1.3. Aims of the Study and Overview of the Project**

This study focuses on the design and construction of a bamboo dome to draw attention to sustainable materials. One of the main questions addressed is what kind of facilities and difficulties a renewable and environmentally friendly material such as bamboo brings to the production process of a dome-shaped building. Both the physical properties of the material and the technical details encountered during the application are reported in this context. In this context, all stages from the construction stages of the bamboo dome to the design of connectors integrated with digital fabrication and the implementation of facade cladding strategies are discussed in a specific sequence and methodology.

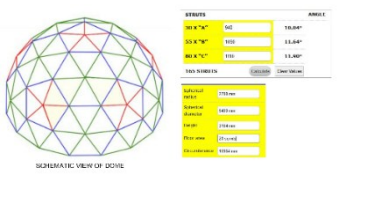
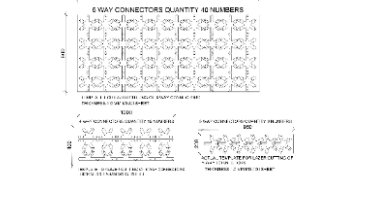
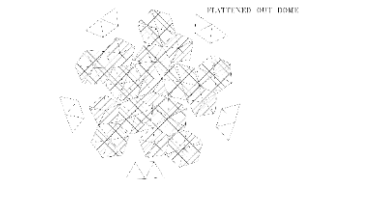
Finally, it is analysed how the connection details developed with digital fabrication techniques work in integrity with a traditional material such as bamboo and what effects this integration has on both structural and aesthetic levels. This investigation is planned to be carried out using a number of comparative criteria. Through these questions, the project is not only a design experiment, but also claims to offer a new perspective on sustainable building technologies.

**2. Material and Methods**

This chapter provides a comprehensive discussion the methodological approach, the materials used and the implementation steps followed during the realisation of the bamboo dome project. This project, which combines a natural and sustainable material such as bamboo is blended with digital production techniques, has enabled both the re-evaluation of local material in a contemporary context and the creation of an educational experience space. Under the following subheadings, the methodological framework of the project, from design to material selection, from digital production processes to construction practice, is detailed under the following subheadings.

**2.1. Participants and Design Approach (Students, Instructors):**

The project is an applied design process carried out within the course on collaboration with Designhub India (Design Hub India, 2025). The participants first took the first steps of the design by deciding together on the area and height of the bamboo dome to be designed on the ground. Then, the geometrical structure of the building was modelled in digital platform (Table 1-Fig. 1); the lengths of the bamboo struts and angles at the joints were determined by necessary calculations. According to the calculations made in this study, three sides of each triangle ABC struts are varying dimensions. In this case, strut A is 870mm Strut B is 1025mm and Strut C is 1200mm. The position and function of each bamboo struts in the load-bearing system was clarified in line with these calculations. Special connection elements were designed for the joints of the rods that form the structural system of the building, and digital production tools were used in the production of these elements. At this stage happens mainly in the laser cutting of connector modules using galvanise sheets with exact configurations of various joints, namely six pro five pro and four pro connectors cut out of a single sheet run through a CNC machine, minimising wastage and optimising accuracy and precision (Table 1-Fig. 2). The process continued with a detailed analysis of the triangular modules that make up the surface of the dome and the extraction of the extensions of these surfaces in the two-dimensional plane (Table 1-Fig. 3). In this way, a comprehensive technical scheme was created to facilitate the manufacturing process and guide the assembly phase.

Modelling of Geometric Structure	Connector Design Template	Flattened of Triangular Surfaces
		
<p align="center"><i>Table 1-Figure 1</i></p>	<p align="center"><i>Table 1-Figure 2</i></p>	<p align="center"><i>Table 1-Figure 3</i></p>

**Table 1:** Design by Designhub India, Vasanth K.Bhat, 2025.

## 2.2. Material Choice and Design Process

Bamboo struts with a diameter of approximately 5-6 cm were preferred as the main construction material for the project. This choice was preferred both for the sustainable nature of the material and for its lightweight yet durable structure to meet the structural requirements.

The connectors used to join the bamboo struts together are made of galvanise sheets (t=1.5 mm). the flexible structure of the steel allows the connector to take shape in the x,y,z plane.

It was also considered how digital fabrication could be integrated into the design of a sustainable building; in this context, several alternative connection details were modelled using Rhino, a parametric design tool. These prototypes were tested directly on the structure and the flexibility brought by digital fabrication to the design process was observed.

Different materials were tried for the surface cladding; a process that was informed by discussions between the students and the project coordinator. Joint decisions were made on issues such as how the materials would be joined and what kind of visual and structural effects they would create. They discussed how to use both digital design and fabrication tools and traditional hand tools in the design process.

## 2.3. Two Stage Construction Process

Bamboo Dome construction consists of 2 stages. The first stage is the construction of the Geodesic Dome design together with the participants, the second stage is the cladding of the facade surfaces.

### 2.3.1. Stage 1: Dome Construction/Workshop

On the first day of the fieldwork, the professor from India and his team gave a comprehensive briefing to the students participating in the workshop. During this briefing, the structural logic of the geodesic dome, the support principle and the installation process were explained in detail. Previously made drawings of the structure were distributed to the participants, so that each student had the opportunity to understand the process both verbally and visually.

After the theoretical transfer, the practical phase started. The bamboos to be used in the construction of the dome were transported to the workshop. In line with the calculations made beforehand, the bamboos were divided into three different length categories. These categories were classified with coloured tapes for convenience during installation: red, black and yellow (Fig. 4).



**Figure 4:** Moving the bamboos to the workshop and cutting. Own Source, Abanoz, B., 2025.



**Figure 5:** Identifying the colors of bamboo and testing the connector. Own Source, Abanoz, B., 2025.

The cutting process was carried out with great care. Each bamboo struts was cut to specific dimensions according to the category to which it belonged. Steel connectors previously produced by CNC cutting were tested in the workshop (Fig. 5). Once the exact locations of the joints on the bamboo had been determined, the holes were drilled. However, the ends of the bamboo were thinned where they approached the connector. This intervention made the assembly phase more practical and stable (Fig. 6).

Connectors were mounted to the red marked bamboos in the workshop (Fig. 7). This preparation saved time on site and allowed for a more controlled construction process. All bamboo and auxiliary materials such as screws, nuts and spanners were transported to the installation site Construction was carried out step by step.



**Figure 6:** Identifying the connection points on the bamboo and thinning the ends of the bamboo. Own Source, Abanoz, B., 2025.

This method was applied in accordance with the self-supporting principle of the geodesic structure. During the installation, everyone took on specific tasks and the process was coordinated with guidance from the guide drawings (Fig. 8). The group work created an environment of effective co-operation and co-ordination between the participants and ensured that the installation process proceeded in a planned and efficient manner.



Figure 7: Adding a connector to the red marked bamboos. Own Source, Abanoz, B., 2025.



Figure 8: The process of building a geodesic bamboo dome. Own Source, Abanoz, B., Grunwald, G.

## 2.3.2. Stage 2

### 2.3.2.1. Coating of Triangular Surfaces Ideas

After completion of the load-bearing frame of the structure, the surface coating process, which constitutes the second phase of the project, was started. This process is a creative design atmosphere in which the exchange of ideas between the students is intensified. The materials and shapes of the cladding were discussed and different approaches were developed. You can see a few of these designs in Figure 9. Each proposal was evaluated in terms of both aesthetics and functionality, and different ideas that reflect the character of the structure were put forward.

In addition to the work done in class, ideas were taken from artificial intelligence during this process. The design ideas obtained from artificial intelligence have broadened the students' perspectives and enabled them to offer different interpretations. At the end of this process, the surface coatings will be applied in accordance with the selected designs, and the structure will achieve its final form with visual integrity.

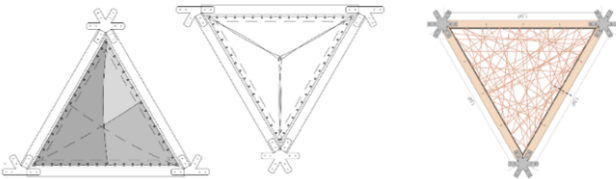


Figure 9: One of the design examples considered in class. Source: Solga, N., Solga, N., 2025.



Figure 10: Results of the second workshop

### 2.3.2.2. Stage 2: Coating of Triangular Workshop

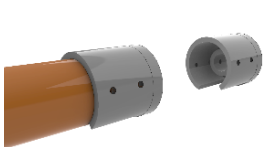
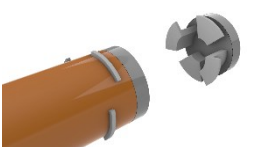

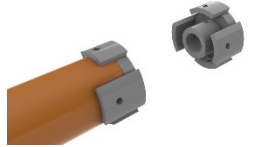
The focus of the second workshop was covering the triangular facade surfaces of the bamboo dome. The workshop started early in the morning, and each student began creating their own facade elements. During this process, accessible and sustainable materials such as fabric, wooden panels, leftover bamboo struts, rope, and bamboo strips were used. The connection details and material usage were customised for each student's design. Each surface was a different experiment: some panels had tightly stretched fabrics; in some surfaces, textured surfaces were created by weaving bamboo strips. Ropes were used to create geometric or organic patterns in the triangular openings. Plywood panels were designed with openings of varying patterns and sizes. Through these patterns, a rhythmic and layered appearance was achieved on the bamboo dome facade. This hands-on process allowed participants to explore the functional and aesthetic potential of each material, resulting in unique yet harmonious facade elements that enriched the overall structural and visual quality of the building. (Fig. 12).

### 2.3.3. Stage 3: 3d Printer Manufacturing Connector

The project also aims to integrate digital production tools. In this context, the potential of connection elements that can be produced using a 3D printer has been explored, and various design ideas have been developed. Additionally, approaches to producing complex designs using a 3D printer have been evaluated, drawing on the work of Hanke, Kawasaki, and Grunwald (2023).

Four different connector designs were developed. The first design is a model that wraps around the bamboo cane approximately 270 degrees from the outside and fixes it at two opposite points (Table 2-Fig.11). The second design has a snap mechanism that fits into the gaps in the bamboo and works with a snap mechanism (Table 2-Fig. 12). The third design has a structure that wraps around the bamboo from three points of varying width and length (Table 2-Fig.13). However, as the angles are not symmetrical here, the fourth design was developed as an alternative, as it is difficult to open an opening for the bamboo: in the fourth design developed, the fastener wraps around the bamboo from four different points, again using the snap-fit method (Table 2-Fig. 14).

These ideas have been digitally modelled and have not yet been physically produced and implemented( Table 2).

Connector idea 1	Connector idea 2	Connector idea 3	Connector idea 4
			
Table 2-Figure 11	Table 2-Figure 12	Table 2-Figure 13	Table 2-Figure 14

**Table 2:** Connector Modelling for 3D printer. *Own Source, Abanoz, B., 2025.*

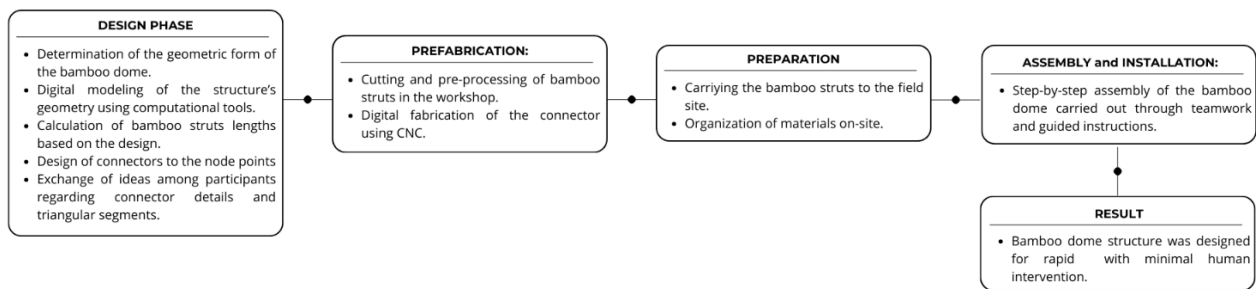
### 3. Results

The field production process carried out on site was documented using observational qualitative data collection methods. The construction process was photographed, and the materials used, technical details and workflows were noted.

The construction process was completed within the scope of a Indo-German international project in a collaborative working environment. The assembly of bamboo struts was easily carried out according to pre-prepared schemas. Connection points were quickly established, and the bamboo dome was constructed in step by step. During the construction process, structural elements were carefully cut, assembled, and secured.

The entire team worked together according to the previously prepared guidelines, and the dome was assembled in a short period of time. The timeline of the bamboo dome construction is illustrated in Fig. 11.

The construction process was not only a physical production exercise but also a valuable interactive learning environment where mutual interaction and experience sharing came to the fore.



**Figure 15:** Timeline of the bamboo dome construction, *Own Source, Abanoz, B., 2025.*

### 4. Discussions

This project provided an interactive learning experience for participants from different cultures working together in a limited time. As a collaboration between India and Germany, this process was not only a construction project but also a comprehensive example of intercultural communication, quick decision-making, and material-based design.

The bamboo dome was constructed on-site by the students through direct manual labour. The physical production process was transformed into a collective experiential space for the students. Throughout the project, students were able to directly experience the challenges encountered on-site and develop solutions, which enhanced their understanding of the typically abstract building production processes in architecture education. Additionally, the integration of digital production tools into the workshop brought new perspectives and speed to the process.

The selection of bamboo as the primary building material provided students with the opportunity to experience a sustainable building material firsthand and confront the limitations of natural materials. Bamboo's flexible structure and high durability created an environment open to solutions on-site, while manual labour and on-site connections ensured that the process remained directly connected to production.

In addition to all this, the bamboo dome has been designed to function with minimal human intervention. This method is viable for disaster-prone areas and rapid construction scenarios.

### 5. Conclusions

The project demonstrated that an architectural process designed and implemented in a short period of time can be transformed into a student-centred learning environment.

This process can be seen as a reflection of the applied learning approaches that are increasingly emphasised in architecture education. In particular, bringing together participants with diverse cultural and academic backgrounds has strengthened not only professional skills but also social skills such as teamwork, communication, and flexibility.

The project created the basis for a hybrid learning environment through the limited but conscious and strategic use of digital tools. In particular, the pre-modelling of certain structural details in a digital environment and the use of these models to guide on-site applications added both technical accuracy and speed to the production process.

The integration of digital production techniques and AI-supported idea development processes into the project demonstrates the adoption of a multi-layered approach. By combining traditional craftsmanship with modern technologies, this approach shows how the relationship between digital technologies and physical production in architecture education can be transformed into a holistic and experience-based learning process.

The ability to construct the structure quickly with minimal human intervention has revealed its potential as a solution for post-disaster shelters and temporary facilities. In addition to shortening the construction period, the construction process represents a positive approach in terms of ecological and economic goals. It provides a strong perspective for future architectural applications.

In future work, repeating this type of layered approach and cross-cultural projects in different contexts could increase the diversity of experiences. In addition, interdisciplinary studies could address the project from different angles. With the wider integration of digital production technologies, construction site production processes could be made even more efficient.

In conclusion, this project represents not only the construction of a building but also a process that brings people together, enables collaborative production, and transforms learning into an experiential process. This approach can be seen as an important step toward establishing a sustainable and meaningful direction for future architecture education.

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