BAMB’UPYOG

A bamboo ecological construction, learning and exhibition centre

Master Thesis Explanatory Document

Akshay Shah

1350290

Supervised by Dr. Dushko Bogunovich and Rau Hoskins

A Research Project submitted in partial fulfilment of the requirements for the degree of Master of Architecture Professional. Unitec Institute of Technology, 2014
Abstract

The title *Bamb’upyog* is a combination of two Hindi words, *bambu* (which translates to bamboo) and *upyog* (which translates to application, or utility). This research project explores the possibility of applying bamboo as a primary material in architecture.

The proposed design is for an ecological construction, learning and exhibition centre, located in Mumbai, India. The facility is a complex of three distinctly different buildings, dedicated to experimentation, innovation, demonstration and promotion of sustainable construction. The project investigates how such a facility can be constructed by predominantly using bamboo. The Centre is necessary because the current, carbon intensive building practices in India are not sustainable in the long term.

*Bamb’upyog* begins by investigating bamboo as a material, its characteristics, advantages and socio-cultural implications. Current knowledge, use of techniques and similar objectives of showcasing the true potential of this ‘green gold’ are some of the important characteristics reflected in the precedents. The array of precedents yielded a selection of possible construction systems and details. The investigated precedents, coupled with existing information, are significant to the research in providing strategies and guidelines for design. The site and its analysis, and the program development led to organising the site in the form of a campus with three key buildings- a Learning Centre, a Workshop and an Exhibition Centre.

The intention is to change the public perception of bamboo. The goal of the ecological centre is for developing communities to gain and disseminate knowledge and skills for optimising the use of locally sourced materials in a sustainable, socially acceptable and culturally appropriate manner.
Acknowledgements

I would like to express my gratitude and appreciation to my supervisors Dr. Dushko Bogunovich and Rau Hoskins.

I am thankful for their pragmatic advice, aspiring guidance, invaluably constructive criticism, time and support.

I am ever grateful to Brendan Smith for all his effort and enthusiasm to provide relevant research material. I thank David Chaplin and all the tutors for the discussion and critique during presentations.

I dedicate this book to my parents Smruti and Vijay, my brother Vishaal and also thank my grandparents, family and friends for their love and support, making this an inspirational and enjoyable journey.

My grandfather who passed away when I was very young would have been very happy and impressed.
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1.0 Introduction

1.1 Research Question

How can bamboo architecture be used to design and build a facility as a showcase for sustainability?

Can such an architecture inspire communities and instil an awareness of sustainability in them?

1.2 Outline of Project

Bamboo has played a significant role in the lives of people in numerous countries in Asia, Africa and South America. Traditionally, it has been used to construct houses, bridges and other buildings, and has many other utilitarian applications. In recent times, concrete, steel and glass have replaced bamboo as a primary building material in these cultures. Thereafter, bamboo was considered to be a ‘poor man’s’ wood. However, bamboo has been released from this stigma as people are increasingly reviving regional, sustainable technologies. The prospect of using bamboo as a building material in architecture is particularly promising. In this context, the project intends to rediscover the numerous advantages of using bamboo as a primary material in architecture and educate communities in emerging economies to embrace sustainability. The centre, proposed in Mumbai, India, will perform multiple functions of showcasing green design and sustainable technology, educating the people through community events, seminars and workshops and promote bamboo construction techniques. The building project will particularly promote bamboo architecture by involving skilled local artisans and inviting design professionals, architects, engineers and students to attend collaborative design-build workshops. The significance of this project is that not only will it raise the level of ecological awareness of people at a local and international level, but support the local economy of the resident communities.

1.3 Aims and Objectives

Many people in developing countries are oblivious of the detrimental effects of unsustainable practices in their daily lives, particularly in the construction industry. At a local level, the project’s main purpose is to educate and train local communities and craftsmen to confidently combine the use of their traditional building methods with sustainable technologies, simultaneously maintaining an ecological balance. By pioneering an awareness of sustainable living, the aim would be to open new avenues to sustainable building and endeavour to bring bamboo centred building technologies into the conventional construction industry. The hub will commit to teach communities about their relationship with the land and its resources. By showcasing sustainable architecture through embracing the use of green and easily available materials, including bamboo, the proposed scheme will make an extensive effort to accentuate all the advantages of the material over others; eventually leading to
the argument that bamboo can demonstrate itself to truly being a rediscovered material of the future.

1.4 Scope and Limitations

This project deals predominantly with using bamboo as a primary material in architecture.

The scope involves the scheme for an ecological facility in Mumbai, committed to research and innovation, demonstration and promotion of sustainable (bamboo) construction. The emphasis is to design buildings of different scales and typologies, to showcase the potential possibilities of bamboo architecture.

The project strives to address socio-cultural and economic concerns. When these and other implications begin to overly influence and modify the investigation, priority is diverted to the architectural design and aesthetics of the facility. Additionally, visiting the site is a limitation, because of its location in India.

1.5 Methodology

Research through Existing Knowledge

This was carried out through literature and precedent survey. The former included a study of theory and concepts related to the prospective use of bamboo in architecture. Precedents were analysed as case studies, and elements of form and function relevant to the research were proposed as influences on the design.

Research through Design

The design was not only the eventual output, but also the primary mechanism for research. Through the process, issues were identified, design decisions were made and solutions were realised.
2.0 Existing Knowledge

2.1 Why Bamboo?

Simon Velez, a Colombian architect who is a major proponent of bamboo architecture, declares that concrete construction as conceived in developing countries produces cavernous spaces. He claims that we do not originate from caves, but are men of the treetops and come from trees. Even though now we live in caves. He notes that current architecture follows an unhealthy routine which is completely carnivorous. This current state of nature demands that we come back to a more balanced and vegetarian state.¹

This is how Velez illustrates his approach. Though literally architecture does not eat anything, it does, however, consume and devour enormous quantities of energy. Additionally, it also takes energy to build them. This is embodied energy, which is all the energy necessary to extract, manufacture and transport its materials, to assemble and finish it.² He notes that like eating, constructing has an impact on the environment. In order to build, things must be removed from the environment either directly or indirectly. Vegetarians argue how much energy it takes to produce meat, a practice which is having a detrimental effect on the environment.³

By describing the need of a more vegetarian architecture, Velez uses a pertinent metaphor.

In this context, today bamboo can be one of the keys to promoting the principle of sustainable development in architectural practice and the construction industry. This long and organic grass stem grows very quickly, often up to 15 meters in the first year, acquiring its peak structural strength in about three years.⁴ As will be investigated later in the project, bamboo is capable of being used for numerous building purposes, the potential range of which have been underrated till now. Once mature, entire poles of cultivated bamboo can be used within cities or their outskirts, providing a continuous yet renewable cycle of supply of this ecologically exemplary building material.⁵ Advantages include that bamboo can replace many tropical timbers and therefore help protect the rainforests; it converts more Carbon Dioxide than most other plants and is very cost effective and easy to work with. Because of its unique characteristics, every part of the bamboo culm is fully utilised, thus producing virtually no waste.⁶

³ Frey, Simón Vélez, 13.
⁵ Ibid., 30.
Figure 1 - Bamboo Raft

Figure 2 - Bamboo Basket

Figure 3 - Bamboo Furniture

Figure 4 - Bamboo as Food

Figure 5 - Bamboo Design Products

Figure 6 - Bamboo Bike
2.2 Socio-Cultural Significance

Bamboo has played a significant role in the daily lives of people in Asian countries like India. As illustrated on the preceding page, the array of traditional to contemporary uses is vast.

Bamboo has always been an object of reverence in the Indian culture. According to Indian legend, the Lord of Fire, Agni once fled to the safe haven of the hollow interior of a bamboo cane. Which is why till date, during auspicious ceremonies, a bamboo cane must be used to dig out earth, forming a receptacle in which the holy fire is then lit. The adjacent images portray the more tactile uses which include a unique way to dry clothes, a traditional lathi (staff) used by the authorities as a symbol of law and order, and as a stretcher which is used to carry the dead in a ritualistic procession to the crematorium.

Due to its strength, bamboo has been used as scaffolding for several years. Some of these spectacular structures can reach up to 70 stories high. Throughout India, but particularly noticeable all around Mumbai, one can find these scaffoldings come up in only a few days. Many celebratory, ceremonial and temporary structures which mark a sacred area and serve as a congregation space are also built with bamboo. A Mandap is a platform or a pavilion set up for weddings and religious ceremonies. A Pandal has a similar function, but is a much bigger structure which has a bamboo matted roof and can accommodate large groups of people. Along the coastline of India, are installed the fascinating fishing nets, whose structure is made up of bamboo and timber.

7 Vegesack, Grow Your Own House, 179.
8 Ibid., 141.
Figure 10 - Workers setting up scaffolding

Figure 11 - Scaffolding on a multi-storey building

Figure 12 - A bamboo Mandap for a wedding

Figure 13 - Bamboo Pandal under construction

Figure 14 - Decorated Pandal for ceremonies

Figure 15 - A bamboo village hut built on stilts

Figure 16 - Indian fishing net
Figure 17 - Indian fishing nets
Keep in mind the aforementioned properties, uses and advantages of bamboo, including its unbeatable value for money. One would think it would be perfectly apt to utilise bamboo as a building material in India. On the contrary, people there still tend to accept higher costs of concrete and steel because they symbolise the modern world in the same way as do cars or TV’s. The material that had been used for many years was later relegated to the rank of a poor man’s wood under the pressure of cultural models imported from the so called developed countries. Thereafter, bamboo has not always been socially acceptable. In the common man’s eyes it represents the poverty from which he had fled. Yet, as discussed before, it is quite contradictory since bamboo is used as an everyday commodity.

Architect Chris Precht argues that the modern and industrial approach to architecture and construction side-lined the already well-known advantages of bamboo and unsustainable practices contributed to the damaging effects around the world. This is true, since current building sector practices in Indian cities like Mumbai are threatening the natural environment and its ecology. The negative effects of uncontrolled growth and development are part of the immense wastage maintained by an extreme cult of “modernity whatever the cost.” The industrial giants and the public have been indifferent to the consequences of their choices, amounting to professional and civic irresponsibility. This needs to change. It would be naïve to think that current building sector practices would have a sudden transferral.

However, as noticeable today, there is gradual change; leading architects are liberating bamboo from its stigma and are giving it more credibility. What is required to achieve a favourable outcome is an ethical approach, clarity in ideas, a civic sense of obligation, creativity combined with pragmatism and new skills acquired through experience.
2.3 Temporary to Contemporary

Bamboo, once a ‘poor man’s timber’, now ‘green gold’ needs to be utilised in such a way as to make its performance reassuring. Proponents of bamboo architecture point out the common misconception that bamboo is only in the realm of temporary structures. This is due to little or no knowledge regarding preservation after cultivation. Today, techniques are better established and treatment of poles is the key. Treated poles can last decades and this can encourage its usage in more permanent structures. Treatments can either be non-chemical, which are traditional methods, or chemical. Selecting an appropriate method depends on various factors. The latter is now better suited for structural applications which need long-term protection. The chemical used in this process is actually a naturally occurring salt of boron (Sodium Borate) which is a safe and environmentally friendly preservation compound. This linear treatment process will be explored later in the project as an influence on the design research.

An essential aspect of bamboo architecture today, as noticeable in the designs of Velez and in his contemporaries’ approach is the notion of protecting by design. Devices following certain criteria are put in place to protect the most fragile parts of the structure. Bamboo culms must be protected from direct ultraviolet rays. To solve this, the roof should have large overhangs that shelter the façade and framework. To protect from water and damp, the supports should be above and away from the ground. The range of measures, added to the aforementioned treatment to protect the culms, gives these works of architecture a durability quite unlike anything achieved by traditional vernacular constructions in the same material.

Because bamboo is hollow, it is connected differently as compared to wood. An array of methods currently exists and newer techniques have been experimented by the likes of Buckminster Fuller, Renzo Piano, Shigeru Ban and Arata Isozaki. Methods range from simple bolt/pin, lashing, and adhesive techniques to complex joints used by Velez. He established a method of crafting strong joints by injecting canes with cement and then inserting steel plates and screws.

18 Frey, Simón Vélez, 60.
22 Frey, Simón Vélez, 71.
23 Ibid., 71
24 Vegesack, Grow Your Own House, 9.
An important aspect of this project is the idea of knowledge sharing through collaboration and dissemination of skills, experience and information. *Mastering Bamboo* author Pierre Frey argues about the notion of a new vernacular architecture.  

This involves taking the traditional cultures and materials from the art of building and nourishing them with the creativity and proficiency of professionals trained in architecture and engineering. Sustainability and an integrated approach are important characteristics of this idea that can bring together representatives of the developing countries as equal partners in a successful exchange of ideas with those of developed nations.  

A symbiotic relationship between tradition and technology can lead to a positive outcome that is socially acceptable, culturally appropriate and ecologically beneficial.

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25 Frey, Simón Vélez, 46.

26 Vegesack, *Grow Your Own House*, 10.
3.0 Precedents

3.1 Green School Bali

3.2 ZERI Pavilion EXPO 2000

3.3 Ecological Activity & Learning Centre
3.4 German-Chinese House EXPO 2010

3.5 METI Handmade School

3.6 Blooming Bamboo Home
3.1 Green School Bali

Figure 29 - The Heart of Green School - The most elaborate structure on the campus has three interweaving cones comprised of swirling helixes.

Figure 30 - Elevation

Figure 31 - Plan
Location: Bali, Indonesia. 
Designer: John Hardy / PT Bambu. 
Environmentalists and designers John and Cynthia Hardy, who have been residing in Indonesia wanted to encourage its people to embrace sustainability. Their aim was to show them how to build with sustainable resources, particularly bamboo. They instituted the Green School, an educational village community, to spread this noble message through an alternative education system. The School’s mission is “Empowering global citizens and green innovators who are inspired to take responsibility for the sustainability of the world.”

Hardy founded PT Bambu, a company which endorses the use of bamboo as a primary building material. Its team of talented architects, designers and craftsmen have built various bamboo structures on the sustainable campus neighbouring the Green School.

Building Materials / Technique

Locally sourced bamboo, cultivated using a sustainable approach is used in an experimental and innovative manner to validate the true strength and architectural potential of the material. The buildings are made almost entirely out of bamboo. The straw roofs are adapted from local tradition. The school includes spaces for assembly, classrooms, housing, offices and cafes. The site features an array of different spaces ranging from smaller teaching spaces to much larger multi-story communal gathering spaces.

Of the six chosen case studies, this “Greenest School on Earth” is one of the largest, in terms of scale, and is more organically shaped.


Figure 35 - Central column structure

Figure 36 - Spiralling roof allows daylight inside

Figure 37 - Bamboo roof
Positive Aspects / Influential Elements

Experimentation through testing and combining traditional techniques with innovative solutions led to the creation of awe inspiring spaces.

Open learning spaces devoid of walls have a huge impact on the learning process. The distraction, in a good sense, of the natural outdoors creates a unique environment that inspires people to be as innovative and creative as the surroundings.

The campus has a very small impact on the environment. The design incorporates natural light, and ventilation keeps the spaces cool. The school is off-the-grid since it operates on a combination of solar, micro-hydro power and biogas systems.
3.2 ZERI Pavilion EXPO 2000

Figure 41 - ZERI Pavilion in Colombia
**Location:** Manizales, Colombia (present)  
Hanover, Germany (demolished)

**Design:** Simon Velez

This 2000 square meter bamboo pavilion was assembled for the ZERI (Zero Emissions Research and Initiatives) Foundation at the Hannover Expo in 2000. Because of strict building regulations in Germany, a 1:1 scale pavilion was constructed in Colombia first, to undergo tests. This pavilion still stands, whilst the one in Germany was demolished after the Expo. ZERI did not construct this magnificent structure just for the sake of building it. It was a major effort to remove the previous stigma attached with using bamboo and change its image. The intention of this unique building was to instil pride in and stimulate the use of this advantageous material. The pavilion was well received and attracted 6.4 million visitors during the 5 month Expo.\(^{29}\)

The bamboo pavilion is now a landmark in sustainable architecture.


Figure 42 - ZERI Pavilion interior
Building Materials / Technique

The building, using 4500 bamboo culms, was erected without cranes by about 40 specialised workers in nearly 3 months.\textsuperscript{30} The floor plan has a 40 metre diameter and 7 metre eaves. The built area is 1650 m\textsuperscript{2}, plus a 500 m\textsuperscript{2} gallery on the second floor.

True to Velez’s philosophy of protection through design, the roof overhang is larger than necessary since it protects the space and structure from the elements.

The roof is covered with a metallic mesh of plaster, topped with 3 centimetres of cement mortar and cement tiles reinforced with bamboo fibres.\textsuperscript{31} Compared to the chosen precedents, and existing bamboo buildings, this pavilion is one of the few circular shaped examples.

\textsuperscript{31} Gernot Minke, Building with Bamboo (Basel: Birkhäuser, 2012), 132.
Positive Aspects / Influential Elements

The innovative structural detailing by Velez creates many possibilities for the future of bamboo architecture. A new benchmark was set using an otherwise underappreciated material. The pavilion was acclaimed for its safety and structural stability since it exceeded the requirements and expectations of the Germans.\(^{32}\) It managed to do so while remaining true to the initial intentions and maintaining its essential character as designed.

Its circular construction and openness is described by ZERI as a space without a beginning or an end, inviting everyone to participate without any obstacles. “It symbolizes a universally accessible organization which embodies concepts and technologies which are applicable anywhere and accessible to everyone.” \(^{33}\)

\(^{32}\) Frey, Simón Vélez, 62.

3.3 Ecological Activity and Learning Centre

Figure 48 - View from downhill
Similar, in its function, to the Green School, this ecological centre at the Soneva Kiri Resort in Thailand provides visiting families with kids a wide choice of entertaining, engaging and informative activities. In a fun and inspiring atmosphere, the objective is to raise their level of ecological awareness through such activities. The interior houses a cinema/auditorium, library, and an art and music room, inspiring children through creativity.

**Building Materials / Technique**

The main structure of this Manta-ray inspired building was constructed using bamboo culms with lengths up to 9 metres and a diameter of 10-13 centimetres. The secondary roof and ‘belly’ structure was made from culms of 4 metre lengths with a diameter of around 5 centimetres. The culms were bundled, and inspired by Simon Velez’s technique, bolted joints were filled with cement. A combination of this and traditional joints were used.
Figure 52 - Evening view

Figure 53 - Two anchoring columns
Positive Aspects / Influential Elements

Similar to most other bamboo projects, the aim is to change the bad reputation of bamboo by inspiring people and architects and showcasing the potential of using it for modern and complex designs.

The design incorporates bioclimatic aspects to suit the humid tropical site. Similar to Velez’s concept, the roof cantilevers up to 8 metres, acting like a big umbrella which provides shade and protection from heavy rain. The open design, translucent elevated rooftop and setback floors allow natural ventilation and the use of natural daylight. This limits energy consumption.

Figure 54 - Interior
Figure 55 - Music room - with a bamboo reed frame
Figure 56 - Connections - pinned with nuts and bolts
Figure 57 - Bamboo roof tiles

Ibid.
3.4 German-Chinese House EXPO 2010

Figure 58 - Exterior - Entrance
**Location:** Shanghai Expo, China

**Design:** Markus Heinsdorff

This building was part of a large event series ‘Germany and China - Moving Ahead Together’ in China, and it presented itself as an architectural highlight at the Expo 2010. It was the only two-storey building at the Expo whose load-bearing structures were made of bamboo. The building reflected the emphasis and theme of the event series, which was sustainable urbanisation. The aim was to promote the use of natural and sustainable bamboo in innovative ways as a construction material.

Heinsdorff had already constructed about 20 bamboo pavilions prior and chose the material because of its traditional and cultural heritage in China.

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Building Materials / Technique

The 2 story building is 8 metres high with a footprint of 25 x 10 metres. The interior has an exhibition and a conference space. The roof is held up by 8 metre long culms of giant bamboo with a diameter of up to 23 centimetres, which are connected with steel and concrete, similar to Velez’s technique. Unique laminated bamboo frames were devised to support the upper floor. The external façade uses a light-permeable EFTE membrane covering and the roof is a PVC membrane. The approval process was a first-time procedure related to permission for bamboo construction in China. The pavilion not only housed exhibitions, but itself became an exhibit.

37 Minke, Building with Bamboo, 142.
Positive Aspects / Influential Elements

The building was designed with a lot of attention to detail. The design combined the use of bamboo with high-tech components and materials. The outcome was a successful, futuristic and multifunctional building which was mobile and recyclable.

The combination of China’s traditional and cultural heritage with Germany’s precise, high-tech engineering was a stylistic amalgamation of both cultures. The floor, structure and even the built-in furniture use bamboo.

New and innovative details had to be worked out to pass every elaborate approval procedure, which once again proved the capabilities of bamboo.

Compared to many other pavilions at the Expo, this one stood out since all its components were either recyclable or could be disassembled and reused elsewhere at any time and in various ways.
3.5 METI Handmade School

Figure 68 - Front view
Location: Rudrapur, Bangladesh

Design: Anna Heringer

This ‘handmade’ school was constructed by local craftsmen, teachers and pupils along with a team of European architects, craftsmen and students. METI’s (Modern Education and Training Institute) philosophy is learning with joy. Children are encouraged to cultivate their potential and utilise it in creative ways, in a responsible manner. The building reflects these ideas through its architectural design, and in the use of materials and techniques. One of the many aims of the project was to develop traditional building techniques, maintaining sustainability by harnessing local potential and reinforcing regional identity. The strategy was to train the local population, develop their knowledge and skills, and encourage them to make the best possible use of sustainable and locally available resources.

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Building Materials / Technique

Traditional local materials including bamboo and earth were used, and local techniques were adapted and improved for better durability. The ground floor walls, made of compacted earth using techniques similar to cob walling, support the upper floor made of bamboo. The bamboo framework was developed using 1:1 prototypes. The cladding is made of bamboo strips. Bamboo culms are connected using steel dowels and bound with nylon rope. All construction work was undertaken by hand, with the exception of an electric drill, which was used to bore holes.

**Positive Aspects / Influential Elements**

This building, which won the Aga-Khan Architectural Prize in 2004, is one of the best examples of successful humanitarian architecture using locally available materials, especially bamboo, resources and manpower. The overall intention of the project and its multiple aims were noble in their cause. The scheme truly proved how a combination of thoughtful yet detailed knowledge of context, simple yet effective design, involvement of local and traditional practices, and the participation of local communities can change their perspectives. The building instils self-confidence and independence, and strengthens their sense of identity. An important aspect is how good design can lead to socio-cultural upliftment and improve the economy and ecology of developing societies.
3.6 Blooming Bamboo Home

Figure 79 - Prototype design
This prototype bamboo dwelling was designed and built with the intention to be mass-produced and sold as an attractive, yet affordable house. The dwellings, which can withstand heavy floods, can be built by owners within 25 days. The prototype is placed on stilts and is built around a bamboo frame which can be adapted to suit individual needs of users. Locally sourced materials including bamboo and coconut leaves are used. The modular prototype though originally planned to be a house can be modified to be a classroom, community centre or a medical facility. The aim was to set up a basic and adaptable piece of vernacular architecture which would be culturally appropriate, socially relevant and responsive to different climatic conditions.

Figure 81 - Main living space

Figure 82 - View from mezzanine

Figure 83 - Adaptability - Screens and roof ventilators are operable
3.7 Concluding statements & learning outcomes

Information extracted from existing knowledge and precedents has emphasised ideologies, tools and techniques which influence the project and can be explored in the design.

The precedents share certain common aspects in their function, materiality and ideology. They strived to change the public perception of bamboo and proved its capabilities. Most proponents of bamboo architecture do not portray themselves to be purists. They, in fact, accept limitations and encourage bamboo use to be complemented with other materials and techniques. As evident in the case studies, a symbiosis of the low and high tech creates newer possibilities.

In most cases, walls which have no load bearing properties are omitted, opening up the interior spaces to the exterior. In developing countries where the culture and social structure is different to the western world, such buildings portray themselves to be more welcoming.

Simon Velez argues that bamboo architecture is synonymous with roof architecture. He designs the roof first and then the space beneath. He notes that roofs in such buildings have two important functions; they provide protection from the elements and always reflect the culture they are from. This is evident in the precedents, and their designs also correspond to Velez’s idea about protection through design. Pierre Frey argues that modern architecture has dematerialized perceptions of architecture, and introduced an increasing distance between a building and its users. Thus making its architecture impossible to mentally assimilate. But under the roofs of the precedents and in their spaces, the experience is different. These buildings are more engaging, and people imagine themselves assembling the structure. This concept is an influential element used later in the research project. Frey concludes that in this immediately present identification of the material elements and traces of workmanship there is a reconciliation of architecture and life.

Velez talks about the local pride of such pieces of architecture; “it is a cultural statement- to create something momentous- a sort of exhibitionism without showing off.”

Figure 84 - Concept for multiple dwellings

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41 Vegesack, Grow Your Own House, 46.
42 Ibid., 59.
43 Frey, Simón Vélez, 126.
44 Ibid., 126.
45 Vegesack, Grow Your Own House, 59.
4.0 Project Development

4.1 Site Criteria

An underlying question Simon Velez always addresses in his projects is how he would build it.\(^{46}\) The question, relevant to this research project, can help determine decisions regarding logistics, proximity to skill and labour, material availability and how it would be supplied to the site. Other criteria the site needs to correspond to include its location and exposure, and its integration of the local communities and the general public.

4.1.1 Site Location

The site is the well-known Mahim Nature Park (MNP) in Mumbai, India. This ecological educational park, also known as the Maharashtra Nature Park, was the brainchild of Shanta Chatterji who was the Chairperson of the World Wildlife Fund (WWF). This plot of land was then being used as a dumping ground for waste, and Chatterji who was quite concerned about the environment and its conservation managed to convince the government to get the area earmarked as a bird sanctuary.\(^{47}\) This was the result of an idea that struck her in the late 1970s, when she noticed different varieties of birds that flocked the Mahim Creek. After years of hard work, the MNP was opened to the public in the 1990s and became a success story. The park, the first of its kind in India, boasts a variety of flora and fauna and because it also functioned as an education centre for students of environmental studies, it became a favourite for schools.

Viewing aerial photos of Mumbai, the site which is part of a larger green reserve in the west, is clearly visible as a prominent ‘green lung’ right in the middle of Mumbai City. The location of the site is very unique because of its context and strategic position. North of the site runs the Mithi River, which divides the city and the suburbs. MNP also is part of and shares its boundaries with Dharavi, a region which arguably houses the largest slum in Asia.\(^{48}\) This whole region is considered prime property because it lies right in the middle of Mumbai, which is India’s financial capital. It is thus not difficult to notice that the nature park is right next door to one of the most densely populated areas in Mumbai. The circular building in the park currently functions as an ecological education centre which houses an amphitheatre, a library, an audio-visual room and a multifunctional space which is used for community events, talks and cultural or social gatherings. Because of its strategic location, the park attracts many visitors who either need to quickly surround themselves with a relatively green and unpolluted area, or are conscious about the environment and want to learn more about conservation and sustainability for a better ecology.

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\(^{46}\) Frey, Simón Vélez, 54.


The Mahim Nature Park Society, which maintains the property and runs its daily activities from the round Education Centre and Park Office building is now looking to expand its facilities to cater to the growing number of nature enthusiasts. The society, backed by the Mumbai Metropolitan Region Development Authority (MMRDA) is inviting suggestions and calling for comments and ideas for redeveloping the park.49 They aim to increase the educational value and effectiveness of programmes, and require better facilities and infrastructure to do so. This scenario fits perfectly with the research project, and the site provides an excellent opportunity to showcase all the aforesaid advantages of using bamboo.

Analysing the site using the aforementioned criteria, including location, exposure, logistics and proximity to skill, labour and materials as follows-

As mentioned before, the site, because of its strategic geographical location in the middle of Mumbai, is easily accessible. Beneficial for logistics as well, since it is well connected by roads and public transport, which includes a main bus depot just across the road and several train stations within walking distance. The Mithi River to the north is being planned by the government to operate a ferry service in the near future. The main entrance currently is in the south, which is accessible to pedestrians and vehicles. This ‘Green Lung’50 of Mumbai is very well known and locating the project here is significant because of the site’s exposure.

Bamboo, being the primary material required, can be easily cultivated in the park itself. The government is slowly realising the potential of this green gold and has extensive plans to popularise bamboo plantation in the state.51 Though the time between plantation and maturation of the culms would take a few years, the advantage would make the site self-sufficient with its own supply. In the meantime, bamboo culms can be easily sourced in Mahim, which is known for its bamboo wholesalers. Other materials, including steel, tin and fixtures are recycled and processed in the Dharavi Slum, which is also well-known for its metal and plastic recycling industry.

An important aspect of this project is the idea of shared knowledge which involves the collaboration of traditional and cultural skill, materials and techniques with the creativity and knowledge of design professionals. The inhabitants of the Dharavi Slum had arrived from different parts of India and had brought


with them traditional skills and techniques, which are used till today. Many of these slum dwellers work as labourers on construction sites and use these skills to install bamboo scaffolding. They do so by using simple, yet effective techniques which have been passed down for generations. The skilled slum dwellers, thus, who live just across the road from the site, will play an important role in the construction and in the daily activities of the facility. Professionals, trained at the University of Mumbai, north of the site, who have knowledge about the high-tech and sustainable practices would then have a symbiotic relationship with the skilled artisans from the south.

This site, thus becomes a melting pot of the skills, experiences and knowledge.
Figure 91 - Context Map
Though vegetation is dense in the western part of the site, the eastern end is relatively open.
4.2 Program

The site will function as an ecological construction, learning and exhibition centre constructed primarily with bamboo. The facility will perform various functions.

By pioneering an awareness of sustainable living amongst visitors, the centre will commit to teach them about a symbiotic relationship with the land and its resources, and the attached ecological benefits.

At a more local level, the facility will educate and train craftsmen, construction workers and slum dwellers to confidently combine traditional building methods with sustainable technologies. Their hands-on skill and expertise, combined with the knowledge and ideas of design professionals will lead to concepts and experiments in bamboo construction technology. These advances in bamboo building techniques will then be showcased to inspire visitors. By doing so, the eventual objective would be to open much needed new avenues to sustainable building. The ecological centre will endeavour to promote and bring bamboo centred building technologies into the conventional construction industry.

Visually and spatially, the architecture will aim to inspire anyone who visits and enters these spaces.

The most prominent feature in the design will be the aesthetic and structural use of bamboo poles.

Other important features include the requirement of the centre to be sustainable, adaptable and inspirational.

Client: The Mahim Nature Park and its educational building is currently operated and maintained by the Mahim Nature Park Society. This organization which comprises of government officials and the general public is backed by the MMRDA. Thus the Mumbai Metropolitan Region Development Authority and the Mahim Nature Park Society would be the clients.

The project will explore three different scales of design. These three buildings will have their own unique function and form. Inspired by the current knowledge and precedents, the design process will apply relevant criteria, different bamboo construction techniques and building typologies, in order to showcase the potential of a sustainable bamboo architecture.

The design process will involve functional planning, form and material exploration, visual aesthetics and spatial experience.

The research, its process and outcome will address these four architectural aspects- Formal, Structural, Functional and Environmental.
Building A - Learning Centre

The learning and training building will be the pilot project on site. Inspired by scaffolding and traditional techniques in Mumbai, this building will be the outcome of the first collaborative effort between the local community (which includes skilled construction workers) and the design professionals. The finished building will be the ‘brain’ of the proposed facility, where the regular collaboration between these two parties will take place. Ideas and concepts will then be created and presented to the visitors. Enthusiastic visitors who would be interested to take part would be able to do so. The slum dwellers and workers, who are part of the team, would be inspired by the design of this building and use it as a precedent for their own dwellings. This is because the materials used to construct Building A would be easily available, and its techniques would be known to them.

Building B - Workshop

Once the facility is well established with an on-site supply of bamboo from plantations in the east, the workshop would be constructed. It is assumed that the collaborative team has considerably progressed in terms of its skill, knowledge and technology, and increased its strength in numbers. The workshop would be the largest structure and would require the combined use of steel and concrete alongside bamboo. Part of the existing education building will be demolished and its concrete would be recycled for the workshop. Metal can be sourced easily from Dharavi, across the road. The slum is well renowned for its metal recycling industry. Bamboo culms would be treated here and used for testing and fabricating concepts developed from the Learning Centre. The large interior space would enable production of treated bamboo poles, ready to be used in construction. Prefabricated bamboo columns, trusses and modular structures would also be manufactured, exhibited and sold.

Building C - Exhibition

The existing educational building on site will continue conducting its daily activities, but parts of it will be demolished. The original intention was to completely demolish it to make way for a new bamboo construction. During presentations and critique, a valid argument was put forward that this intention did not suit the theme of sustainability, which is a major driver in the research. Through analysing other possibilities and concepts, it was mutually agreed that the existing building, with its stable and permanent concrete skeletal structure, could be used to support a regularly replaced/rebuilt roof and façade structure. Concepts originating from the Learning Centre would be tested and manufactured in the Workshop, and eventually be displayed in the Exhibition Centre. These would either be as prototype connection and joint details, composite columns and trusses, or as roof and façade structures. With the latter, the building itself becomes an exhibit.
4.2.1 Layout on Site

The layout of the three buildings is crucial and dependant on their individual function and relationship with each other. Bamboo will be planted in the eastern part, since dense vegetation covers the land west of the existing educational building, in comparison to the east. Therefore, in order to minimise tree relocation, the additional buildings will be constructed between the existing building and proposed plantation. This decision is practical since the entrance is in the south east. Buildings A and B both require to be situated close to this plantation and in each other’s vicinity. Since Building A will be the pilot project on site, it is placed close to the entrance. By placing Building B to the north, a cyclic process is started. The outcomes of collaborative concepts in Building A, will be constructed and tested in the Workshop using culms sourced from the plantation. The final result will then be showcased in the Exhibition Space or on the building itself.
The location and design of the buildings will create architectural vistas, which would attract visitors entering from the main south entrance. Pathways link all the three buildings.
5.0 Design Process

5.1 Building A - Learning Centre

5.1.1 Design Requirements

- A central space for teaching, training and learning
- Separate rooms for group collaborative activities
- Administrative office
- Gallery and information space for visitors
- Possible accommodation spaces
- Circulation

Figure 99 - Spatial Diagram
5.1.2 Design Explorations - Materiality

Procurement of suitable materials is an important aspect of the design process. Materials which are sensitive to the needs and functions of the building will be used. Their use will, in turn, influence the form, function, structure and aesthetics of the building.

The criteria for the Learning Centre involves the use of easily available materials and techniques known to the people of Dharavi, since they will be a large part of the workforce. Possible combinations of materials will be considered in the design explorations of form and structure.

**Base:** To protect the bamboo culms from direct ground contact, moisture and surface water, they can be pinned to a base. This base can be a mixture of locally sourced clay, dirt, recycled cement and water, which is made in a mould to be cast as a block. Before this base mixture solidifies, a metal rod will be used to anchor the bamboo columns.

**Columns and structural frame:** Techniques, derived from bamboo scaffolding joinery and connections, will be used to create bamboo columns. Multiple culms will be lashed using coir rope/twine, made from coconut fibres which can be sourced from palms on site. Other structural elements, including beams, trusses and purlins can be pin jointed using steel bolts. These can then be lashed.

**Roof:** The roof can use corrugated steel or plastic sheets, which the existing shanty dwellings of Dharavi are known for using. Dharavi’s thriving recycling industry\(^2\) is known for its ability to recycle anything that can be reutilised. The steel and plastic required for the building process can thus be sourced from across the road.

Bamboo culms, cut in half, can be flattened and used as roof shingles.

**Floor:** The floor will be constructed using bamboo either as whole culms, woven strips or flattened culms which can form boards.

**Walls:** Boards similar to the ones used for flooring can be used. Bamboo lattices, which have an aesthetic appeal, can also be used.

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Figure 100 - Bamboo culms
Figure 101 - Coir twine
Figure 102 - Corrugated steel / Bamboo roof
Figure 103 - Making base blocks
Figure 104 - Bamboo lattice wall
Figure 105 - Bamboo board floor
In order to address the functional needs and derive the required form and structure, prefabricated components are devised. These column and beam components are made up of bamboo culms which are bolted and lashed. The column is made up of 3 culms; 2 outer layers for load bearing, with the interior pieces at either ends to prevent twisting. This layer also helps keep the ends of these columns stiff and stable. The gap, as seen in Figure 108, is where the beam or truss is fixed with bolts and lashing. The combination of these is tested in the sketches above. From sketch I to II, the beams are rotated upwards to form a gable. This is suitable to disperse rainfall. Triangular configurations are well suited for bamboo structures, and as apparent in the precedents, they have an aesthetic yet functional role. Sketch III creates a gull wing roof. Though this configuration facilitates ventilation, it relies on the central column for load bearing. Sketch IV thus creates a hybrid of II and III, and the exterior columns are load bearing. This makes the interior plan footprint free of unnecessary columns.
Carrying on from the chosen sectional sketch, this assembly process explores how the arrangement of the prefabricated elements in three dimensional space can generate form, and how the structure can be used to define space.

1. The base blocks with the metal re-bars are set on level ground, ready for the prefabricated columns.

2. Once the bamboo culms are assembled as columns, according to the requirements, they are positioned on the bases and then concrete is poured into holes. These are drilled at the bottom of the columns, ensuring an anchored connection, reinforced by the metal bars.

3. The groove in the first column is where the first beam is positioned. It is then bolted and lashed with coir twine.
4. The second beam is then connected to the second exterior column. This beam is different, since it sandwiches the first. The joints are pinned and lashed again, and this creates a rigid frame.

5. Another set of bamboo components frames the load-bearing column. The combination of these beams creates the base for a dual pitch roof.

6. The finished module from step 5 can now be duplicated along an axis. By omitting the central column and moving it to the exterior modules, the structure now starts to suggest a demarcation of the space in between.

This model can now be applied to create the functional spaces, and the componentry can be manipulated and arranged in different ways to suit the scale and address the necessary requirements.
Individual Group Spaces

Figure 110 - Assembly
The collaborative group activity / studio spaces are divided into separate modular pods. These are the smallest individual units in the building. Spacing the separate frames at equal distances as illustrated in image I, the structure is then braced laterally using bamboo culms in step II. The culms at ground level form the floor frame, and the ones at ceiling height brace the whole module. In step III, bamboo purlins of a smaller radius are attached to the frame and the roof made up of flattened bamboo shingles is installed. Image IV shows how the interior is enclosed by the bamboo walls and floor. This space is able to accommodate small teams, which are part of the larger collaborative group. These modules are then arranged on an axis to form a cluster around the main central space. As the design progresses and develops, the centre’s circulation, and its functional layout is addressed.

Figure 111 - Individual group spaces
Administrative Office

Figure 112 - Multiple floor assembly
The administration office space is spread over two floors. This building needs a bigger footprint and the structure is expanded horizontally and vertically. The floor plate is stretched to double the length as illustrated in image II. Image III shows the bamboo joists on which the floors sit. All the prefabricated elements of the upper level are then attached to the bamboo posts, and then the roof and walls are installed.
Figure 116 - Deriving the structural frame
The visitor information space and gallery is located in the building which also forms the entrance to the Learning Centre. Spatially, the interior has to be free of supporting structure, and both long and wide enough to accommodate bigger groups of people. The previously devised base module is tested in two possible combinations. In step I, the fronts of the frames are attached. The footprint generated is too wide and though the central space is column free, the posts required to support the frame divide the interior into three parts. Since this is not favourable, step II illustrates attaching the frames back to back. This frame requires the supporting column right in the middle of the space. This is not practical either, but the triangular frame, pointing outwards and upwards creates a better aesthetic and prominent element. The solution only requires the parameters of a specific component in the basic module to be adjusted. As demonstrated in images III to IV, the frames in their original form are overlapped, but the beam in image IV is now the connecting element which merges the separate frames into one. This clearly highlights the advantages of using the basic module as a primary system, which can be altered to suit the structural and spatial requirements. This frame is now multiplied along an axis.
The bamboo floor is installed and the roof, unlike the previous buildings, is made up of recycled corrugated sheet metal. Because this pavilion is longer than the others, installing a corrugated roof is more practical. Questions relating to access, privacy and enclosure, which have not yet been addressed in detail, can now be explored in the entrance building. As illustrated in the previous iterations, the ceiling spaces are deliberately left open to allow cross ventilation. The exaggerated roof overhangs protect the spaces underneath from rainfall, and also provide shade.
As gathered from the literature research and precedent survey, walls in bamboo buildings have no structural role. They are used to delineate space. In the illustrations above, two types of exterior walls are tested. The bamboo panel in the first case can be used in situations where privacy is paramount. But in this case, where the objective is to showcase, using the lattice wall is more favourable. Not only is it more appealing aesthetically, but facilitates ventilation.
The bamboo lattice panels are operated by hand and can be swivelled to gain access into the space. Depending on the requirements at different times, the panels can either be rotated or left shut. Since the floors are elevated above ground level, access is gained via bamboo steps.
As the individual spaces in the Learning Centre take shape, the plan is developing simultaneously. Even though the visitor information building is the first to be entered from, the central activity space is the heart of the hub. The group studio spaces radiate from the central space, where all the circulation paths converge.

Since all the floor plates are elevated, connecting the separate spaces requires a circulation pathway which is constructed at the same level.

Figure 121 - Spatial Planning and axonometric
Central Activity Space

The central space is similar to a traditional Indian courtyard. The various spaces all radiate from it and all circulation paths cross and meet here. To enable the space to be used in all seasons, it is decided that this courtyard be sheltered. Since the surrounding roofline is at the same level, the roof of the central building and its supporting structure would have to be elevated to provide daylight and facilitate ventilation.

Bamboo posts support the gable roof. The modules are stacked side-by-side. In the first case, the frame and roof configuration provides good shade and rain protection. The second alternative can provide additional daylighting, but is not suitable during the monsoons.
This is remedied by using a smaller roofing unit which uses recycled corrugated plastic sheets. They block rain water, but allow sunlight to pass through the translucent material.
Whilst developing the form and interior of the central space, it was pointed out in a presentation that the interior columns could hinder the functionality of the space. Since the intention is to provide an open space for large group activities, the comment is valid.

In the first illustration, the columns have a strong visual presence because of the perspective. This may be suitable to suggest and define circulation paths.

But in the second image, the interior columns are replaced with beams, which transfer the load to the peripheral columns. This enables the floor plate to be utilised for its envisioned purpose. The exterior columns, as in previous modules delineate the space.
### Developed Plan

1. Information Space / Gallery
2. Central Activity Space
3. Individual Group Studios
4. Administrative Office
5. Circulation Path

Figure 125 - Developed Plan
5.1.3 Design Outcome - Spatial Experience - Visual Journey through the Learning Centre

The Learning Centre is the first group of buildings visitors see when entering the site. The first image illustrates this viewpoint. The second is viewed from the pathway which leads north to the workshop building. In this image, to the far left is the administration office. It is located strategically because of its proximity to the learning centre and its functions, the workshop, bamboo plantation and the exhibition space.

The image on the adjacent page illustrates the operable façade of the visitor information space. The bamboo lattice panels which swivel, can be operated by hand and multiple configurations are possible. The second example shows the panels, which correspond to the circulation paths and entrances, are open. The third scenario is possible to accommodate larger groups and facilitate cross ventilation. The facade, coupled with the strong visual lines created by the roof structure portrays the building to be more welcoming and accessible.
Figure 127 - Operable façade
Figure 128 - Information Centre / Gallery Interior
The visitor Information Centre is the first building in the group that forms the Learning Centre. Visitors, including design and construction professionals, architects, engineers, builders and the general public are introduced to the site and its facilities. Information regarding the ecological centre, its aims and operations, is displayed in the gallery space. Work in progress and finished models made to scale in the central training space are displayed here.

The public is informed about the advantages of embracing sustainable materials and products in their daily lives.

After the brief introduction, groups may either visit the other spaces in the Learning Centre, or carry on to the Workshop and Exhibition Centre thereafter.
Design professionals and enthusiastic visitors are able to take part in the collaborative process. This team already includes the residents of Dharavi, University faculty and students, and trained professionals who are being trained to hone their skills. This space, which forms the ‘heart’ of the Learning Centre, performs multiple functions. Groups formed into separate collaborative teams will be trained in this space and will learn about sustainable building practices and technologies. Theory workshops relating to bamboo treatment, construction and connection detailing will be organised.

Using this knowledge, the group will separate into their teams and occupy their pods, which are the individual studios constructed around the periphery. These teams discuss how they would use the acquired knowledge and skills to design prefabricated bamboo components, including composite columns, beams or trusses. Once their knowledge and skills increase, these teams would then be able
to design prefabricated bamboo structures and buildings. The bamboo panel walls enclose the studios and can be easily replaced with the aforementioned screens. These components which can be easily clipped on or off, and replaced, allow flexibility in the functional use of the spaces.
The staff on-site use this building as their base. The trainers and team leaders collectively discuss the agenda for an upcoming project or workshop, and then carry on their tasks in the Learning, Workshop and Exhibition centres. NGOs and support groups who manage the collaboration with slum dwellers will also occupy the space.
Relevance to slum dwellers

One of the key aspects of the Learning Centre is the use of prefabricated bamboo components which are relatively simple to construct. The driving force behind this feature is the notion that the slum dwellers would be able to construct the group of spaces and familiarise themselves with the techniques involved. Building A is therefore extremely important and relevant to the locals of Dharavi. Their involvement in a building project such as this, uplifts their ‘social status’ and provides them with income.

The other main driver and advantage of the design and its characteristics is that Dharavi residents can use the centre as a model, on which they can base the construction of their own dwellings and workplaces.

1. The smaller individual studio spaces can be adapted to be used as single family dwellings.
2. The office space is double the width and height, therefore joint families with many members can occupy the double-story dwelling. Bamboo screens and mud walls can be added for privacy and to divide the space.
3. The central space can function as a shared communal space. The slum dwellers are known to have a social relationship with each other and this space can thus be used by them.
4. The visitor information centre has been designed such that it can perform multiple functions. NGOs can use the space as a community medical centre or school.
5. Future dwellings and buildings can be constructed in a cluster along the bamboo pathway.

Figure 134 - Plan adapted for slum use
5.2 Building B - Workshop

The function of the workshop requires the design and form of the building to incorporate a linear process of bamboo production. Similar to a factory production line, the processes are grouped along an axis and thus a rectangular floor plate is suitable. As illustrated below, suitable bamboo culms from the plantation are selected, cut and treated. Concepts derived from the Learning Centre are then tested and built. Thereafter, the outcome is showcased in the Exhibition Centre.

To maximise usable floor space, the structural supports need to be located around the periphery.

The spacing of structural elements needs to be wide enough to allow for easier manoeuvrability of long culms. Similarly, the interior spatial volume needs to be large enough to accommodate machinery and tools.

Other spaces include storage for tools and machinery, and spaces for staff and the collaborative team members.

Figure 135 - Spatial Diagram
5.2.2 Design Explorations

The design process is initiated by using a triangle in elevation as a basic element. This is replicated along an axis to derive the required form. Using this basic shape for the structural elements is advantageous because of the inherent strength achieved. One side of the triangle forms the floor, whilst the other two form the roof / structure.

Illustrated here is a model of a self-supporting structure designed by Leonardo da Vinci. This structure has the ability to be erected quickly, using pre-built pieces which are slotted in place.

This principle can be used as a precedent, as the structure relies on its own weight for stability. The interior is free of supports, which is an added benefit.
This alternative uses a simple structure. Posts support the roof structure which is made up of beams at either end of the roof. The load is transferred down into the columns. With this arrangement of columns, the usable floor space is divided into three parts. The central space is the largest, and the other two are smaller.

This configuration provides good shelter from the sun because of the overhangs. The height allows natural light and cross-ventilation.

But the spans are too long and the structure needs to be more robust. It would be preferable to have the columns around the periphery to maximise floor usage.
Alternative 2 is inspired by da Vinci’s self-supporting structure. Multiple canes attached together are used for the structure. This technique adds strength and is able to span more than the previous alternative. The overlapping structural elements are pinned, creating a rigid frame.

Though larger in scale than alternative 1, the structure appears more robust. The position of the columns at the edges of the floor provides more usable area.

With this configuration, the roof line is lower than before. This will not be suitable since there will be less air-flow and natural light, as compared to alternative 1. Though both scenarios require the use of steel, neither uses concrete. The bamboo columns are attached directly to the ground, and as previously discussed in the research, this is not recommended. Concrete columns can be used, with supporting bamboo poles used for roof framing and as beams.
5.2.3 Design Outcome

By extracting the advantages and merging the two alternatives, a third is achieved. This hybrid structural frame incorporates the use of concrete columns. The vertical column transfers the load of the structural frame to the ground. The slanted column not only shares the load, but braces the whole structure along the X axis. Bamboo culms are pinned to the concrete columns using steel joints. These steel connectors also join different bamboo poles.

The overhangs protect the structure and space below. Natural daylight and cross-ventilation is achieved by raising the bamboo frame and pinning it to the concrete base columns. The main purpose of the workshop is to provide space for experimentation, building and testing prototypes, which can then develop into finished products. Treated poles and prefabricated elements will be sold locally or transported to parts of India.

Not only will this process generate income and provide jobs for the slum dwellers, but simultaneously ensure a sustainable procedure. This is achieved because the zero-waste process utilises all the parts of a bamboo culm. By-products can be reused, and bamboo offcuts can be stripped or flattened to create shingles or panels. Offcuts and bamboo saw dust can also be used as fuel to generate energy.
Laying out the frame in three-dimensional space, it is noticed that bracing is strong along the X axis. Even if this component is multiplied to create the form, there is no bracing along the Z axis.

By rotating the bamboo roof frame on the Z axis, two twin frames are created. By doing so, the load is now shared between two concrete base columns. The frame is now well braced along the Z axis.

This component can now be duplicated side by side. The structure is compared to a tree. The concrete columns form the trunk, and the bamboo framing elements are similar to the branches.
Individual prefabricated units are devised to accommodate storage spaces. These units are placed in between the columns. Their position corresponds to the relevant function of a particular space in the workshop.
Figure 144 - Workshop axonometric and plan
Spatial Experience - Visual Journey through the Workshop

Figure 145 - Workshop Entrance - North South axis

Figure 146 - Workshop Entrance - West East axis
5.3 Building C - Exhibition

5.3.1 Design Requirements

The existing building onsite currently functions as an environmental and ecological education facility. As illustrated in this image, the concrete structure is based on a radial grid. Columns define separate spaces. Of these 8, 4 are enclosed with walls. The remaining 4 are open to the exterior. In the middle is an open courtyard which can be accessed from all the spaces.

Since the existing building function aligns with the research project, it was decided that the core structure should remain, only demolishing parts of the roof and walls. This provides a permanent structural skeleton which supports a bamboo roof, that can be replaced or rebuilt.

Figure 149 - Existing Building Plan
The minimal demolition involves deconstructing the inner walls of 3 spaces that provide access from the exterior. This enables cross-movement axes which provide circulation. The 4 enclosed spaces will perform their original functions, and the other 4 open spaces will be used for exhibitions and other events. An amphitheatre is added in the central space. Talks, exhibitions and events related to advances in bamboo construction and ecological education will be centred in this space. The surrounding spaces and their functions will then complement this space.
5.3.2 Design Explorations - Concrete Skeleton Structure

The existing structure comprising of concrete columns and beams.

Walls divide spaces into 4 enclosed and 4 open spaces.

Concrete roof with an opening in the middle.
Beams of the 4 open quadrants are removed. The ring beams at the extremes remain intact.

The walls remain in their original position. Only the interior walls of 3 quadrants are removed.

The ceilings of the 4 enclosed rooms remain untouched. Only the roof/ceilings of the open spaces are demolished.

Figure 152 - Exhibition Building Structure
Figure 153 - Alternative 1 and 2
The bamboo frames in alternatives 1 and 2 rely on all the concrete columns for transferring their load. It is noted that the open spaces have no middle columns, thus these alternatives are not suitable. With alternative 3, the concrete columns at either end support the bamboo frame.

The frame, illustrated below, uses bent bamboo poles which support the rafters of the roof.
A bamboo dome is constructed using prefabricated bent culms. A ring at the top creates an oculus.

Bamboo Columns emerging from the concrete columns at either end are attached.
Figure 156 - Roof Frame Assembly

Bamboo rafters are attached.

Purlins added to attach roof on.
The roof is thatched using local materials sourced on-site. Coconut and palm leaves can be used. These materials are easily available and simple skills are required to construct the roof.

Similar to the previous buildings, the roof protects the spaces from the harsh sun, and provides ventilation. As illustrated in Figure 158, the elevated roof allows air to pass through. Warm air then rises and escapes through the oculus, creating a chimney effect. All the three buildings incorporate this design principle of ventilating and cooling the spaces naturally. The existing centre already collects rainwater and has solar and photovoltaic panels. The proposed buildings will also be able to generate their own energy and collect water off the roof.
5.3.3 Design Outcome - Spatial Experience - Visual Journey through the Exhibition Centre

Figure 159 - Entrance - The four open quadrants each form an entrance into the central space. These spaces are dedicated to the functioning of the Bamboo Ecological Education centre. The other four enclosed spaces are used by the existing education centre. Depending on different scenarios, there can be a crossover. Exhibits displayed include finished prefabricated bamboo elements, joinery techniques and models.
Figure 160 - Interior - Since the beams above the open spaces are omitted, bamboo culms emerge from the ring beams on either end.
Figure 161 - Amphitheatre - The open and enclosed spaces are radially located around the central space which is an amphitheatre. Lectures, functions and events can take place here. Large scale bamboo exhibits are displayed, and visitors can circulate around them. The bamboo dome with its oculus covers this space and creates a strong visual aesthetic. The structure in itself becomes an exhibit.
Figure 162 - Circulation - A pathway around the amphitheatre facilitates circulation around the building and into the different spaces.
5.4 Developed Site Plan

Figure 163 - Site Plan.  A - Learning Centre  B - Workshop  C - Exhibition Centre
Unsustainable construction practices and uncontrolled urban growth around the world have put immense strain on our environment. One particularly detrimental effect is the deforestation due to timber harvesting. The other is the enormous carbon footprint of the modern construction materials—cement, glass and steel. Thus the construction industries in developing countries are the ever greater source of the destabilisation of the global ecosystem.

As we seek more environmentally responsible ways to build ever more buildings, we too often forget the solutions from the recent past. Bamboo used to be the dominant construction material in India. Its useful features and advantages are exceptional and transcend the boundaries of architecture and construction. Coincidentally, the plant originates from developing areas, where the need for building sustainably is the greatest. This is all the more reason that it is an apt solution.

In this context, Bamb’upyog explored how bamboo can be used as a primary material in architecture, and to further emphasize the point culturally and economically, the programme selected was for an educational and experimental facility whose main task is to promote sustainable building practice. The major aim was to educate the masses by creating an awareness of sustainability, and encourage them to embrace practices that respect ecological boundaries of this planet.

The first step to understand bamboo as a material involved exploring its properties, advantages, traditional uses and socio-cultural significance in India. Bamboo, though a symbol of religious reverence and cultural importance has a social stigma too. Another important factor to understand was the general notion and misconception that bamboo can only be used for temporary purposes. The chosen precedents backed the argument that such was not the case, if appropriate skills, technique and knowledge were combined.

The research by design segment of the project involved designing the Ecological Centre, organised as a compound which consists of three buildings. Each had a different role and thus the opportunity was to demonstrate three different functional, structural and formal strategies. The chosen precedents were relevant to the three different scales and functions.

The design outcome successfully addressed the aims and objectives of the project. Furthermore, important aspects including visual, environmental, socio-cultural and economic features were addressed.

Visually, the aim of the spaces was to inspire and create a sense of awe; without creating a mystery of ‘how was this built?’ All the elements, joints and structural systems are visually exposed. The strong aesthetic character and legibility of the bamboo structure make it possible for visitors to get inspired and imagine themselves assembling its elements.
The design not only achieved its purpose of pioneering an awareness of sustainable building and living amongst the general population, but also endeavoured to introduce bamboo centred building technologies into the conventional construction industry. This was attempted by creating three buildings of different scale, each with a unique palette of materials and structural solutions. These buildings themselves became a showcase of the various possibilities that can be achieved. The zero-waste attribute of bamboo combined with other sustainable materials that ‘grow on the doorstep’ added to the environmental merit of the project by minimising the need for logistics. Furthermore, the buildings can be easily dismantled, and individual components can be replaced and recycled. Such criteria is often difficult to meet using conventional materials and methods. Lastly, the buildings are designed in a way which maximise natural or passive ventilation, cooling and lighting, to reduce the need for external energy. The complex also harvests its own water and processes its own waste.

The Bamboo Ecological Centre becomes a place where knowledge and skills are attained and validated. By implementing such a mechanism in a developing country, the activity on such a site generates income and supports the local economy. The project plays a formative role, providing a social structure and enhancing the status of those involved.

The buildings, especially the Learning Centre, emphasise the notion of growing one’s own house. Individual communities in Dharavi can plant bamboo and grow it for their needs. Knowing how to use this ‘veritable steel of vegetable origin’ for construction is an essential element of general knowledge in the culture.

When the users of the buildings are themselves involved in their construction, a close and spiritual relationship is developed. Architect Dylan Baker-Rice adds that bamboo is rooted in a historic vernacular unique to many Asian countries. Unlike other materials, bamboo has a relevant purpose and is connected to a place and its environment. Bamboo stands for a symbiotic way of life and for a holistic, sustainable architecture which caters to people’s needs.

\[53\] Vegesack, Grow Your Own House, 153.
\[54\] Ibid.
\[55\] Frey, Simón Vélez, 57.

\[57\] Vegesack, Grow Your Own House, 151.
\[59\] Vegesack, Grow Your Own House, 151.
The project sought to validate the use of bamboo in a region where it is grown locally. By showcasing its strength, aesthetic, ecological and economic advantages, and diverse applications achieved at low cost, the Centre sets an example at a local, national and international level. This conforms to the phrase think globally, act locally.

Bamboo architecture is also proving to be a suitable alternative in earthquake prone areas. In fact, it is suitable as an insurance against all sorts of disasters. In the age of climate change, and for a particularly vulnerable nation, such as India, the Bamboo Ecological Centre (BEC) would assist in the development of a resilient, self-supporting society. While the project originally sought to enrich the community’s diversity and cultural heritage, and link them with the task of sustainability, it is now clear that this project has a secondary, but vital task. This involves strengthening the self-reliance of local communities, and thus improving their chance of survival in the stormy decades ahead.

There are many possible directions for this project in the future. One is to seek real life application. This may happen by proposing the designs to the Park Society and the Mumbai City Council.

The second direction could broaden the research into the social, economic and cultural pragmatics of the Centre. At this stage, the project may be deemed a good piece of architecture, but other disciplines, including planners, economists, sociologists and environmentalists would need to be involved for a comprehensive assessment. It is to be acknowledged that there may be modifications to the design, as a result of their findings.

The third possible direction could find more innovative ways of using bamboo. The potential of multi-storey bamboo buildings could be investigated. Interesting possibilities could be achieved by using glu-laminated bamboo known as GluBam\textsuperscript{60}, which is a relatively new product currently undergoing tests. The research could also investigate design possibilities in a western context.

Further study could focus on resilience and disaster planning, and inquire if the BEC can be designed and built to withstand any instance of extreme weather.

The Learning Centre and Workshop can be expanded and more buildings on site can be devised to process, protect, produce and promote bamboo, demonstrating itself to truly being a rediscovered material for a sustainable future.

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9.0 Appendix A

Figure 165 - Bamboo Scaffolding - Note the dual-layered structure

Figure 166 - Religious Pandal - With an interior bamboo structure and decorated exterior
Figure 167 - Bamboo roof structure - Note the use of timber poles as well

Figure 168 - Bamboo wall structure
Bamboo Treatment Process\textsuperscript{61}

Select appropriate mature bamboo culms for harvesting.

Wash the poles and soak in a Borax solution. This solution contains Sodium Borate, which is a preservative.

After soaking for a few days, the poles are stored vertically. The sun bleaches the bamboo to a golden yellow hue.

They are then stored in a sheltered and dry place. Hot air is injected to dry the poles quickly and efficiently.

The culms are then sorted according to their diameter.

Poles that crack during the process can be split. These are used to make panels, roof shingles and cladding.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{bamboo_joint.png}
\caption{Joint devised by Simon Velez}
\end{figure}

The Nature Park provides suitable conditions for the growth of many species of flora. Wild bamboo, as illustrated above, grows in abundance.
Site Location and Context

Single Unit Exploded Axonometric
Building A - Learning Centre - Main Entrance
Building A - Learning Centre
Building A - Learning Centre - Section and Night Views
Building B - Workshop - Main Entrance
Building B - Workshop
Building B - Workshop - Section and Night Views
Building C - Exhibition Centre - Main Entrance
Building C - Exhibition Centre - Interior
Building C - Exhibition Centre - Section and Night Views
Basic Prefabricated Component Model
Single Unit / Studio Space Module Model
Single Unit / Studio Space Module Model