

Theme: 3.5. Architecture, Machinery and technologies; Architectural Design

Symphony of the Bamboos

Ar. Neelam Manjunath Proprietrix, Manasaram Architects, Bangalore, India, mansarch@gmail.com
Managing Trustee, Center for Green Building Materials and Technology, Bangalore, India,
cgbmtblr@gmail.com

Notations:

BMTPC-GOI	Building Materials & Technology Promotion Council – Government of India
DEWATS	Decentralised Wastewater Treatment Systems
DFID	Department for International Development
IISc	Indian Institute of Science
IPIRTI	Indian Plywood Industries Research & Training Institute
RWH	Rain Water Harvesting
TRADA	Timber Research and Development Association

Key words: bamboo, building, sustainability, environment, material, energy, resource

Abstract:

Vastushastra (Chakrabarti, 2013) is a science of architecture that combines the five elements of nature and cosmos, ultimately balancing with man and the material. This mysterious science unifies the five elements called *Panch Tattvas*- earth, fire, water, sky and space and paves a way for enlightenment, happiness and prosperity for mankind. We must learn to use these limited resources carefully under the guidance of “The Mother Earth Eco-system”.

This is where we architects can step in - to combine our technological and creative skills with true commitment, and reverse the trend of violence against nature and our fellow beings to promote Sustainable Development and enhance our spiritual end.

Bamboo can resolve the problem of resource equity of natural resources. It can serve the triple bottom-line of Sustainable Development - Environmental security, Economic prudence and Social justice all at the same time. Bamboo together with mud and stone can create a new vocabulary of architecture.

We, at Manasaram are committed to fight back climate change by promoting the use of naturally abundant, easily renewable, low energy, local materials. We have close to 31 years of experience in the field of Sustainable Development. Bamboo was included in our palette of natural materials when a unique opportunity struck us two decades ago.

This paper charts our journey of these two decades with this fascinating material and our agonies and ecstasies along the way. Manasaram Architects presented their work at the prestigious Architecture Expo, Venice Biennale 2016 under the name “Symphony of the Bamboos”.

Introduction - The Genesis

“Nature ... What befalls the earth befalls all the sons of the earth. The earth does not belong to man, man belongs to the earth. All things are connected like the blood that unites us all. Man did not weave the web of life, he is merely a strand in it.

Whatever he does to the web, he does to himself.” – Chief Seattle, 1854 (Rudolf Kaiser, 1987)

Manasara, the celebrated saint wrote the oldest treatise on Indian Architecture Vastushastra, describing the science of design principles for buildings, from which our Studio Manasaram was born (Figures 1, 2).



Figure 1



Figure 2

Man inherited, developed and nurtured this good earth and is nourished by it. Ecological disturbances and environmental problems are posing a grave situation for humanity. The repercussions of our destructive action will be felt for generations to come. Indeed it may take another millennium to put things right. Now is the time to change our consciousness in this regard and come up with appropriate means of utilising our resources. For creating a *Space* for human *Existence* transcending *Time*, it is desirable that the architect designs projects to cater to all the three faculties of Man- Physical, Psychological and Spiritual; possible by using the *Panch Tattvas*, the five elements-Earth, Water, Fire, Air and Space as elements of design.

Working with natural materials in itself has been an eye opener and put us on the path back to our roots. Using what is freely available on the site, i.e. Sun, Soil, Air, Water and Space, and materials that are within our short reach are the determining factors in our designs. Creativity is a mere result of this challenge. Our designs take birth, grow and mature on the site.

Through our design, we initiate the building into the ecosystem at micro and macro level. We strive towards making the building a living entity, responding and growing like any other living being, from dawn to dusk, from spring to summer, from rains to chilly winters. When this goal is met, even to a small extent, the built structure becomes a thread in the web of all life, one with nature, nature itself.

“An architect is a catalyst of change in society, setting the stage for all human activities on earth. As architects we challenge ourselves to achieve a balance between Responsible Creativity and Creative Responsibility in all our projects to arrive at holistic solutions.” -Ar. Neelam Manjunath

It has been over 19 years since we started working with bamboo in our projects and we've never looked back. Our journey has been tough and enduring but truly fruitful and rewarding. Through these years, we have prototyped a variety of building typologies with Bamboo, (Figures 3, 4, 5) ranging from something as small as a low-cost bamboo toilet, to an urban proposal for a Metro Station, (Figure 6) serving a wide spectrum of needs for all the population.

“Symphony of the Bamboos” – charts the journey and evolution of this humble material in TIME & SPACE – from a Poor man’s timber, associated with traditional bamboo communities with untapped potentials – to the Establishment of its existence as a contemporary building material of global importance. It celebrates the triumph of nature, unleashing the potential of natural materials, processes and our symbiotic relationship in conquering new frontiers in Sustainable Development.



Figure 3



Figure 4



Figure 5



Figure 6

Our Muse, Bamboo

“It is no wonder that native craftsmen soon found such a workable material, a broad field for cultivating their genius. Because of its great tensile strength, its capacity for splitting straight, its hardness, its peculiar cross section and the ease with which it can be grown- a combination of useful traits found together in no other plant - Bamboo is one of those providential developments in nature, which like the horse, the cow, wheat and cotton, have been indirectly responsible for man’s own evolution.” (Porterfield 1933)

The giant wonder-grass Bamboo has been around for centuries, serving mankind in a multitude of functions. It had in fact become the Kalpavriksha or the wish fulfilling tree for him. He built his house with it, protected it with Bamboo forts, used it as firewood, made weapons, clothes, musical instruments, and even upon death, he was carried on it and buried with it.

Bamboo plays a key role in the lives of a fifth of the world's population even today, particularly in tropical climates where giant bamboos grow. There exists the tradition of using bamboo for construction of structures such as houses, bridges, tents, scaffolding etc. (Figures 7, 8) In the Indian context, we are the second largest producer of Bamboo in the world and have the best artisans. Bamboo can be a vehicle for integrated Development for our vast rural and tribal population for whom using it is a way of life from time immemorial (Figure 9). Bamboo based communities are considered untouchables in many parts of the world even today. Uplifting the status of Bamboo would translate to uplifting and development of the entire social strata.



Figure 7



Figure 8



Figure 9

Fast forward to the 21st century - the world is gripped by the fear of Human civilization being wiped out by Environmental destruction. Global warming conferences, seminars, workshops, are rallying across the world, talking about the effects of industrialisation and urging the world to 'Connect back with Nature'. In this call for return, this 'Poor man's timber' is being hailed as the WONDER MATERIAL by the Global community, especially by the building sector – 'the largest polluter in the world'.

Bamboo contributes to sustainable development on three fronts:

Bamboo a sustainable Material - Recent research and development has shown bamboo to be extremely resource efficient and versatile material for the building sector, capable of solving major issues of sustainable development especially in developing and under developed countries. This can also resolve the problem of resource equity of natural resources. It can provide cost effective, safe

and aesthetical housing; livelihood security, eliminate poverty and crime; low carbon emissions, fast sequestering of carbon and liquid fuel and energy. That's bamboo for us.

Bamboo the Engineering material - Bamboo can replace many highly processed engineering materials with high energy balance in the construction sector owing to its inherent properties. The physical structure and chemical composition of Bamboo has the properties of highly efficient materials. Its high fiber strength makes it the only replacement for steel especially in small buildings and housing sector that form the largest chunk of construction. It can replace wood in almost all its applications. It forms excellent composites with a variety of materials suitable for many applications.

Bamboo - a Metaphor - Bamboo is a natural, humble, elastic, adaptable, versatile, efficient and holistic material. At Manasaram, we take our profession as service to society- connected to people and nature at all times. We try to be adaptable, versatile and look for simple efficient solutions just like the Bamboo. Secondly, traditional buildings with bamboo are symbiotic and part of our culture. Bamboo in that way symbolises the need of the hour for architecture profession to become Symbiotic and Social, rather than individualistic and elite. Bamboo is a metaphor for the way human existence itself should be on this earth-humble.

Learning from traditional techniques, while improvising and researching on other innovative methods, we can unleash BAMBOO, resisting its inertia of reality and transcending the local craftsman into the larger picture.

The Journey...

We started our journey with a couple of Government projects for research organisations like IPIRTI - a plywood institute, BMTPC- GOI technology promotion council, KARNIK- a govt. executing agency, TRADA, DFID, etc, as architectural consultants till about 2003. So we had cooperative clients, funding, executing agencies, research backing by the institutions etc so it was somewhat easy going. However, there were a few problems like that of quality of execution which could not be questioned by us due to the involvement of high profile bodies. But the major disadvantage was that they were considered lab tests only due to the nature and size of the projects. General public couldn't relate them in their daily life and so projects were very difficult to come by from the building sector.

In our enthusiasm and desperation to prove to the world, the potential of this wonder material bamboo we started taking even the smallest projects like a pergola, a shed, single gazebo's etc. From projects of budget in millions and an office strength of 25, we were doing projects of few thousands with no fees or minimal fees and 1 staff. Since there was, and still is a serious dearth of data and precedence for us to follow, the amount of effort was 5-6 times more than an average project with 5-6 times less fee since the project cost had to be minimal to be accepted by the client. No architect wanted to work for me, no admin and no contractor wanted to take up my projects for execution.

As my name as "Bamboo architect" started rising, my professional practice kept getting reduced to project size of lesser than a struggling architect. I received awards and recognitions on one hand, but projects continued to be shelved, scrapped, etc until I finally completely lost my practice with no project in hand.

And at that point I realised that if I myself am not in mainstream practice, I will never be able to mainstream Bamboo? I tried reading about other architects who had charted similar paths, trying to learn lessons from their past experience.

That was a wake-up call for me to change my approach in dealing with the clients. I concentrated in identifying the issues and carefully started tackling them one by one. And things started changing for the better. I got some awards, presented my papers and projects at national and international forums. We started getting publication requests and we held on to that as our only PR source, since we had no money to do it otherwise.

We have come a long way. It is still difficult to convince clients to use bamboo. But the winds are changing for bamboo, and our practice has now changed levels to projects of budgets in millions to be made with almost entirely from bamboo!

Projects at a Glance

Rebranding Bamboo: Bamboo has a long history as a building material in many parts of the world. It is light, strong and easy to grow. In spite of these advantages, it is widely perceived as a temporary, poor man's material. However, with careful specification and design, a safe, secure and durable bamboo shelter is achievable at a price that is within reach of even the poorest communities in developing countries.

Even when issues of durability and strength are resolved, the question of acceptability remains. A bamboo building need not look 'low-cost' – imaginative design and the use of other locally available materials within the cultural context can make the building desirable rather than just acceptable. In the two decades of our association with bamboo, we have used it in all types and size of projects from housing, institutions, community buildings etc to infrastructure, cultural etc.

We believe that architecture is not just an empty shell of a structure but carries the essence of culture, creation of identity and gives its inhabitants a sense of confidence. That is what we could call social progress. The challenge of our projects is to meet the needs and dreams of the people in an economic, reasonable, ecological, social and aesthetic way.

Housing

Housing is a basic need for humans. Taking into account the economies of scale, our environmental concerns, and HDI (Human Development Index) which is used to measure the quality of life in countries across the world, providing this basic need is a major challenge. India is on the verge of large scale urbanization over the next few decades, and a shortage of housing due to expensive capital, high gestation period of housing projects, low affordability by Economically Weaker Section (EWS) and Lower Income Group (LIG) households are bottlenecks restricting desired growth in housing stock in India with respect to housing demand.

Our concern regards the enormous resource and energy consumption and the carbon emission by the construction industry for even the baseline of our development goals. The sector emits about 22 per cent of India's total annual CO₂ emissions. Bamboo has been proven as an energy efficient material when compared with other woods, steel and concrete (Carolina Lopera, Andres Uribe, 2014). If there

is a way to bring down the carbon emission, and reduce costs of construction, while at the same time making a successful attempt to raise India's HDI, why not give this mission a fair chance to prove itself? Yes, we're talking about tackling issues using Bamboo and other natural materials as alternatives in the construction industry.

For example, The Pradhan Mantri Awas Yojana launched by the Prime Minister Narendra Modi is a vision of Housing for all by the year 2022 with an aim of constructing more than two crore houses across the length and breadth of the nation.

Current state of housing in India-Requirements to achieve the vision by 2022 (Prerna Kuhad, Satish Meheta, 2018).

- Housing shortage of about six crore units
- Prioritized rural growth resulting in uneven distribution of housing development
- Both the central and state governments are spending about three per cent of the current investments in the real estate sector. Using bamboo in mass housing with other materials can help achieve our development goals along with our environment goals.

We have used bamboo in several of our residential projects from a single bedroom house to a large 10,000 sq.ft. upmarket house, and also mass housing projects. While some of the houses are all bamboo houses, other we have used bamboo in combination with other natural materials. The House of Five Elements with area of 10,000 sq.ft., uses over 40 % bamboo in several forms with bamboo crete walling, a 4000 sq.ft. shell roof structure, bamboo ply for furniture, doors, bamboo flooring, bridge, pergola, etc. (Figure 10)



Figure 10

The projects House of 5 Elements, Tejpunj Apartments and Aditigreenscapes E5 are examples of larger residential projects (Figures 11,12,13).



Figure 11



Figure 12



Figure 13

Disaster Relief

Bamboo grows more in areas with high population and high disaster prone areas, which require economical and safe housing. (Figure 14) Safety in built environment is a fundamental right. In the wake of earthquakes, tropical storms and hurricanes, etc, bamboo shelters provide quick, sturdy, humane and cost-effective ways to house thousands of residents rendered homeless and recovering from the disaster, for both interim relief and permanent shelter. It can also help promote employment opportunities for local communities, who otherwise would be struggling to support their families.



Figure 14

Bamboo combined with cement-based mortar can be used in residential construction in seismic regions, particularly in developing countries. Bamboo houses remain serviceable for much longer periods than other forms of housing in disaster prone areas. Bamboo is durable with a minimum life span of 30 years, it can withstand wind speeds of up to 150 km/h, is earthquake safe, waterproof, fire retardant, lightweight, cost-effective and easy to transport and erect.

We have done a prototype house for permanent shelter in Huti Bay in Little Andamans for the victims of the 2004 tsunami. We designed and trained the locals and they built it by themselves. We also designed shelters for victims of the great Orissa cyclone.

Prefabricated houses:

Bamboo construction technique is most amenable to prefabrication either in the form of prefabricated components like trusses, frames, columns, wall panels and beams or as fully prefabricated units, which could be transported. Prefab bamboo walls could be used in high rise buildings to cut down on onsite construction time. Bamboo prefabricated houses have several advantages (Figure 15). To mention a few • They can be easily prefabricated • They can be easily assembled and dismantled • Individual elements can be readily replaced • They are recyclable and biodegradable • They can be kept ready for deployment for disaster relief operations.



Figure 15

Community and Institutional Buildings

A sense of community is vital for any society to thrive. It brings a sense of identity and pride, and is made possible through processes such as communication, inter-group relations and networking. Community buildings play a significant part in the life of many local communities. They play a major part in fostering the concept of people's involvement in development and democracy. They are also very essential for the growth of our rural and tribal sectors. These include but are not limited to education, health care, business, recreation, and spiritual celebration. With bamboo and bamboo artisans available in rural and tribal areas, economical and eco-friendly community buildings can be built with the help of the locals.

We have used Bamboo in all types of community buildings like exhibition centers, farmer's centre, crèche, schools, creativity centre, university buildings etc.

The project Cocoon in Trichy, Tamil Nadu (Figure 16) is a multi-use space that also acts as an exhibition area for KrishiVigyan Kendra, Trichy. Done as a workshop with students of C.A.R.E. College, Trichy and Aarhus School of Architecture, Denmark. Cocoon is a space for teaching and exhibiting projects to visitors of Krishi Vigyan Kendra, Trichy. It is a unique project that qualifies as socially relevant because it connected a wide spectrum of participants in the project and made it a socially relevant one.



Figure 16

Community buildings (Figures 17-19) can be hand-built by local craftsmen, pupils and teachers working in collaboration with Architects and Designers. Local traditional building materials can be combined with new construction knowledge to produce a building that is sustainable, aesthetic and a

value addition and much-needed facility for the community. We try to maintain a commitment to the people and their indigenous building methods and materials.



Figure 17



Figure 18



Figure 19

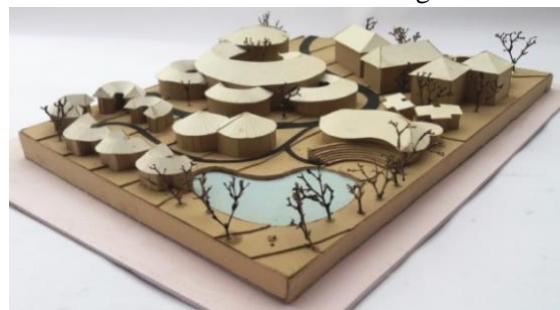


Figure 20

The sustainability institute of CGBMT (Figure 20) will be its headquarters and will integrate all the sustainable technologies in its design and execution through research and development, and will strive to be a torch bearer in the field of sustainable development for the building sector. Materials, water management, energy management, waste management, biodiversity, and social sustainability will be our departments of study for sustainable development.

We have been working with Dayalbagh University, Agra for more than 10 years to start a nationwide skill development programme for the bamboo sector through their 90 plus distance education centres in India and abroad. In 2005 we constructed a bamboo structure (Figure 21) in Dayalbagh University campus as a proof of concept for starting structured courses for the bamboo sector. Now the university has planned bamboo centres at the University campus in Agra, Rajaborari, Madhya Pradesh and Amritsar in India (Figure 22). A Crèche for Dayalbagh's University has recently been completed as well (Figure 23).



Figure 21



Figure 22



Figure 23

Infrastructure

The cities of yesterday are experiencing a burst of infrastructure and building construction activity to cater to the ever-increasing population. Flyovers, roads, underpasses, airport, metro, large condominiums, etc. are being formed, creating unmanageable waste, deforestation on a massive scale, polluting our cities, disturbing the soil strata, water table and so on - an unsustainable Exploitative Isolated approach to Development. In order to reduce the carbon footprint of infrastructure it is important that we account for the energy that is embodied in the materials that we use. Our quest has been to explore the various ways of using materials and construction systems with low embodied energy and carbon, and make recommendations on how to reduce these in infrastructure projects.

Can we see the links between what is, and what can be? For example, Bangalore's Metro System stretches across the length and breadth of Bangalore City linking its important intersections. As of May 2016, there were 31 metro stations in the network. There are 42 stations in total as a part of Phase I. The completed Metro Stations, built with conventional methods, require 1.3 lakh tonnes of concrete, 44,500 tonnes of steel bars, and 190 km of high-tension wires weighing 2900 tonnes. A total of 395 piers, including station piers and portals, were constructed on the stretch. To think, at such a large scale, how much damage the consumption of carbon emitting resources could do, would make us plan with caution the design of these Metro Stations. Bamboo and other natural and local materials can and should be used for larger scale projects as in our Metro Station Proposal for Bangalore (Figures 24-26) Processed bamboo poles and beams with adequate fire rating could be used for the stations. The proposal is under process from the government.



Figure 24



Figure 25



Figure 26

Transport is another guzzler of resources. To help reduce air pollution, conserve energy and be a better friend to our environment, we could definitely start with using our public transport system. We have taken our vision of providing eco-friendly bamboo bus shelters (Figure 27) one step further by organizing a workshop of 45 participants including architects, students, artisans, and 16 street children from the Parikrama foundation, on World Bamboo Day in 2014. We came together to design, develop, and construct a cross-framed structure using bamboo poles and splits in 2 days. The roof was designed using Bamboo mat boards covered with Galvalume Steel sheets.



Figure 27



Figure 28

Swachh Bharat Mission by our PM, is focused on building individual toilets, community toilets and solid waste management in rural and urban areas. The States have the flexibility of design delivery mechanisms that take into account local cultures, practices, sensibilities and demands. The incentive for building toilet has been increased to \$180. We have designed and prototyped a flat-pack flexible toilet shell (Figure 28) which can be used for quick sanitation projects for both temporary and permanent toilets in slum rehabilitation, rural and tribal areas. These can also be used for expeditions and mountaineering, religious gatherings, eco-resorts, disaster relief operations, etc. It is developed by us with PG students of CGBMT.



Figure 29



Figure 30

As proven for many years by traditional construction, bamboo is a very suitable material for small bridges in mountainous areas, lakes, parks, rivulets, etc (Figures 29, 30) due to its strength and flexibility. These could save lot of fossil fuel and carbon emissions. We have done several bridges of different sizes and lengths for both pedestrians and light vehicular movements.

Bamboo Symphony - Lessons from Bamboo

Our office had to embody all our design philosophies along with other requirements of space and services, to serve as an example of our professional practice both existing and in the future. We chose bamboo as the main material for our building and called it Bamboo Symphony. (Figures 31, 32, 33) It connects the past to the future and bridges the gap between the profession of architecture and civil society. We adapted this project to our traditional knowledge, held in the hands of our craftsmen by developing an inclusive systemic process of - Seeing - Listening - Learning - Teaching - Designing and Building.



Figure 31



Figure 32



Figure 33

Mandate: The building is an attempt to rebrand Bamboo as a desirable material and replace steel, concrete and other unsustainable materials. The design showcases the inherent strength of a single bamboo culm, taking inspiration from age-old traditional fishing platforms in India – truly synergetic structures, harmoniously defining the spaces, and creating a feel of extreme lightness.

The structure: The building's most unique feature. (Figures 34, 35) It has been designed as a hybrid of synergetic and tensegrity systems and was physically tested before concreting the roof. Bamboo is the only natural building material with lowest energy balance that can be used for such structures. The columns in BAMBOO SYMPHONY though look haphazardly placed, have definite position,

size and inclinations, i.e., they are 100% structurally relevant, just like the highly evolved technological logic we find in Nature.

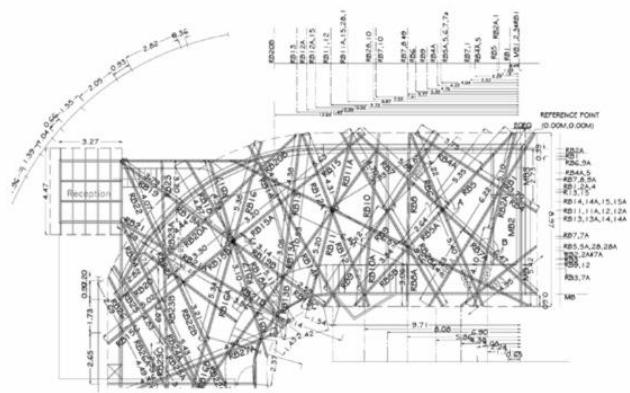


Figure 34



Figure 35

With regards to space planning, the office has an open plan with four split levels, wrapped around a central lotus pool with the Architects' cabin sitting at the bottom level, visually connecting all spaces for easy communications. (Figures 36, 37, 38) The building's orientation and roof form allows for strong North-East and South-West winds to blow over the structure, without any drafts inside, despite the structure being fully open to the South. The RWH pond is landscaped with locally available water plants, enhancing the microclimate and humidity, planned to maximise the durability of the Bamboo members used in the building. The overflow from this pond recharges the Bore well.



Figure 36



Figure 37



Figure 38

The roof was allowed to define its own shape as per the flow of the forces – naturally, like a fabric assuming its shape. (Figure 39) These structures are highly efficient with minimal energy and material use. The slab is cast with Bamboo-fiber Reinforced Concrete (BFRC) which is lighter than conventional concrete, thus reducing the load on the columns, with bamboo splits for reinforcement.

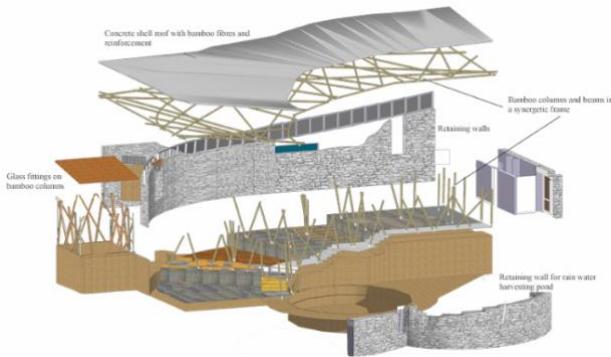


Figure 39

Innovative construction materials and technologies were used such as: Bamboo-crete walling system with precast wall panels; stabilised mud blocks; green shell roof over lattice grid made of bamboo, supported on bamboo columns and beams; bamboo-reinforced concrete with bamboo fibres, enhancing thermal comfort in the interior.

Design process and execution: The design and construction of Bamboo Symphony was done in a truly symbiotic and informal manner along with the artisans and the supervisory staff. This construction system with locally and humble materials like mud, bamboo and stone available universally, can be adopted for several other uses, tested locally by unskilled artisan and constructed with minimal machinery and equipment , at a fraction of conventional construction costs.

It is a Zero Energy Development with a closed loop for Building Materials, Processes and Technologies. (Figure 40)

Building Energy Features	
Location – Bangalore	Built up area – 210 sq.m
Orientation of main facades East-West	Solar energy systems For 100% energy requirement with grid connectivity as standby
Natural Ventilation 100%	Day lighting Approximate percentage of floor area needing artificial light during daylight hours-0%
Night time Ventilation Natural	Energy saving artificial lights Yes, 100% CFL and LED light fixtures
Thermal transmission of building envelope High	Utilization of building mass as thermal storage as part of heat strategy Achieved via passive cooling
Environmental Features	
Materials/ components section - strategy to reduce embodied and transportation energy Bamboo, stone, stabilized mud blocks, Bamboo roofing sheets Bamboo flooring, Bamboo columns and beams	Rainwater harvesting Extensive system with 75,000 ltrs. rainwater Harvesting sumps Zero runoff site/Recharging bore-well All water bodies from collected rainwater
Usage of recycled materials namely Fly ash, recycled wood, scrap metal, stone, debris	Special water conserving fixtures, recycling, and treatment Treated water for flushing, washing , gardening etc.

Figure 40

Consultants: Building material & Technology - Center for Green Building Material & Technology, Bangalore ; Rainwater Harvesting - Prof. A.R.Shivkumar, IISc, Bangalore ; Waste Water Treatment - CDD Society, DEWATS, Bangalore ; Compressed Stabilized Earth Blocks - Dr. Yogananda, Mrinmayee, Bangalore ; Structures - Manasaram Architects

The Journey ahead

Our adventure so far has been one of exploration and intuition, learning from technologies that have existed for centuries and stood the test of time. Traditional technologies in every part of the world are responses to the immediate needs of the local inhabitants perfected over centuries. We have been trying to study these techniques and adapt them to develop a contemporary vocabulary of design for our projects. (Figures 41 – 44) Each of our projects is considered as a research opportunity where we experiment with new forms of construction, materials, etc. which have roots in our traditions.



Figure 41



Figure 42

We are continuing our search for solutions to solve several issues with bamboo like fire rating, colour leaching, joints, database, standards, bonding with concrete and several others.



Figure 43



Figure 44

Data base creation for traditional and contemporary technologies: We are in the process of building a database of Bamboo based traditional technologies for the building sector with our own projects as the starting point. This compilation would give confidence and serve as reference for anyone looking to build with this beautiful material.

Testing and Analysis of our buildings: We are in the process of getting our bamboo buildings tested and analysed and catalogue them along with test results since they are live prototypes of the technologies, construction systems, joints, finishes etc.

Prefab bamboo-crete wall: The versatility of Bamboo is incredible. Even when used as splits, it displays extraordinary tensile strength. 'Bamboo-crete' technology uses bamboo splits and chicken mesh as reinforcement for walls. These are light weight and excellent for shear and curtain walls.

This method of construction is fast and can be employed in various forms of prefab construction, be it small scales shelters or large scale multi-stories and curtain walls for high rise buildings projects. These walls are 2" thick serving as a suitable choice for internal partitions. We have made a prototype in a small structure in 2005 and plan to take it further to the market.

Bamboo-mud-paper blocks: The use of strong bamboo fibres in the mix for stabilized mud blocks greatly enhances the strength of the blocks which are excellent for exterior or interior walling. (Figure 45) We are planning to conduct testing for the block, so that they can be used suitably. By compressing Bamboo and newspaper waste with mud, one can achieve extremely light weight blocks. (Figure 46) It can be a great option for interior partitions and for even making furniture.



Figure 45



Figure 46

Our Orchestra

Because... “*It takes a whole orchestra to play a Symphony*” - Halford E Luccock

Our resource organisations are our orchestra, without whom we would not have been able to reach so far. And only with their and other stakeholders cooperation we will be able to take the bamboo sector forward.

Skill Development is the next big thing. If the sustainable development industry has to grow and develop, skilling in the sector has to be taken in a structured and systemic manner.



Figure 47

- Centre for Green Building Materials and Technology, CGBMT, a sister organization of Manasaram Architects supported by Aditi Constructions & Aditigreenscapes, is a trust started by us as a response to the dearth of awareness, trained personnel (Figure 47) and sufficient data in the field of Sustainable building materials and technologies. Since its inception in 2004, CGBMT has worked towards promotion of Environment friendly solutions for a Sustainable way of living through various fields of research and development with special emphasis on Bamboo. CGBMT runs distance

education courses in 'Bamboo Application Technology' offering Certificate, Modular, Diploma and PG Diploma (online) programs. Our modular programs are recognised by Dayalbagh University, Agra, India

In order to spread awareness and inspire the youth, CGBMT, Centre for Green Building Materials and Technologies, Bangalore and Manasaram also conduct various workshops for Architecture, Design and Engineering colleges, school children, rural women and specially abled, younger generation and the general public to get hands-on experience of the material. Participants are exposed to various techniques of processing, bamboo treatment, joineries etc. and get to make products or build small structures on their own.

- Aditi Constructions have worked with Manasaram Architects for several years now. They have helped us in executing nearly all projects giving expertise in Bamboo related works and enhanced our practical skills which has helped us greatly in our design process.
- The Dayalbagh Educational Institute, located on the outskirts of the historic city of Agra. This university promotes a simple, disciplined and principled life, undoubtedly contributing to the strength of the social, moral and spiritual fiber of the institute's educational system. They understand the great potential bamboo holds for India's development and have integrated bamboo in their curriculum right from 8th grade onwards to the doctorate level through modular courses. We are doing several bamboo based buildings and projects for them.

Bamboo is certainly one of the materials the world will turn to, once we begin to realize the ramifications of using highly energy intensive materials. It is a material of the future and we believe the coming generations will actively get involved in using it for sustainable technologies.

List of figures:

Figure 1: Bamboo Symphony, external view, Bangalore	2
Figure 2: Bamboo Symphony, entrance, Bangalore	2
Figure 3: Cocoon, internal view, Tamil Nadu	3
Figure 4: House of 5 Elements, entrance, Bangalore	3
Figure 5: Tejpunj Apartment's skylight, Bangalore	3
Figure 6: Bangalore Metro Station proposal	3
Figure 7: Traditional bamboo bridge	4
Figure 8: Bamboo fishing nets	4
Figure 9: Bamboo splits structure	4
Figure 10: Bamboo house at IPIRTI, Bangalore	7
Figure 11: Tejpunj apartments, Bangalore	7
Figure 12: Aditigreenscapes aerial 3D view	8
Figure 13: House of 5 Elements, Bangalore	8
Figure 14: Bamboo structure houses in seismic areas	8
Figure 15: Mr. Lunardi's House, Italy	9
Figure 16: Cocoon, Tamil Nadu	9
Figure 17: DEI Guesthouse, Amritsar	10
Figure 18: DEI Guesthouse – construction - Amritsar	10
Figure 19: Playground, Aditigreenscapes, Bangalore	10
Figure 20: CGBMT Headquarters model	10
Figure 21: Bamboo Gazebo at Dayalbagh University, Agra	10
Figure 22: Bamboo Centre proposal for Dayalbagh University	10
Figure 23: Dayalbagh Crèche, internal view, Agra	11
Figure 24: Bangalore Metro Station Proposal	11
Figures 25, 26: Bangalore Metro Station Proposal	12
Figure 27: Bamboo Bus Shelter, Bangalore	12
Figure 28: Flexi-San-Shell portable toilet	12
Figure 29: Yamuna Biodiversity Park Bridge, Delhi	12
Figure 30: Bridge concept at IID	12
Figure 31: Bamboo Symphony Office, Bangalore	13
Figures 32, 33: Bamboo Symphony Office interiors, Bangalore	13
Figure 34: Bamboo Symphony Structural Drawing	14
Figure 35: Bamboo Symphony - construction	14
Figure 36: Bamboo Symphony - plan	14
Figure 37: Bamboo Symphony - elevation	14
Figure 38: Bamboo Symphony - section	14
Figure 39: Bamboo Symphony – exploded 3D view	15
Figure 40: Bamboo Symphony – constructionenergy features table	15
Figures 41, 42, 43, 44: Bamboo Symphony – construction techniques	16
Figure 45: Bamboo fibers stabilised mud block	17
Figure 46: Bamboo, newspaper waste and mud block	17
Figure 47: CGBMT training workshop	17

Bibliography:

- 1 – CHAKRABARTI V., 2013, Indian Architectural Theory: Contemporary Uses of Vastu Vidya, Routledge, ISBN 978-0700711130
- 2 – KAISER Rudolf, 1987, Chief Seattle's Speech(es): American Origins and European Reception, University of California Press, United States
- 3 – PORTERFIELD Willard M, 1933, Bamboo, the Universal Provider
- 4 – LOPERA Carolina, URIBE Andrés, 2014, Analysis of Bamboo as an Energy Efficient Material for Construction, Hamburg University, Germany
- 5 – KUHAD Prerna, MEHETA Satish, 2018, Housing for all: Unleashing the potential, The Economic Times [Accessible at: <https://economictimes.indiatimes.com/news/politics-and-nation/housing-for-all-2022-unleashing-the-potential/articleshow/62711497.cms>]