EXPLORATORY REPORT

JANUARY 2020

TRAINING FOR SUSTAINABLE CONSTRUCTION

A sustainable Home: The Muthiah House In Bangalore

SUBMITTED TO

LabourNet
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PREPARED BY

CLARE

ABSTRACT

A modern sustainable home: No. 9 in Bangalorei

Sustainable buildings displays how changing the methods and inputs during the construction process can make it more energy efficient and reduce the impact on the environment. However, construction of sustainable buildings need knowledge of specific techniques and inputs, knowledge that is not mainstream yet. This report presents an exploratory study into the materials, techniques and training opportunities that are practised in India, though not part of the conventional construction process yet.. The study has two parallel focus points - 1) construction of new energy efficient buildings and 2) energy efficient renovations on existing buildings. The report details the techniques, as well as contacts of people and institutions associated with it. The findings of the research suggests requirement of national level training of masons and construction workers so that they serve to both disseminate knowledge about such practices as well as help implement it.

Keywords: Sustainable buildings, energy efficient buildings

PROBLEM DESCRIPTION

Buildings are a fundamental necessity for a good quality of life. They are fixed assets and have a long operational lifespan. They consume substantial amounts of natural and manmade resources both during the construction and maintenance phase. The Indian construction industry is amongst the largest with respect to demand for raw materials, employment generated, capital input, and even environmental impact (Reddy, 2004). The Construction industry in India is at an average growth rate of 5.6% during 2016-20 period compared to 2.9% during 2011-15 period. This is due to an ever-growing demand for housing and commercial buildings. The excessive demand for raw materials and the consumption of energy resources in building needs to be addressed. This growth in demand has been echoed in the rising demand for building materials like bricks by 2.5%, steel by 5%, and cement by 5% (Pranav, 2019). While the industry is growing, estimates show that over 22% of greenhouse gas emissions come from the construction sector in India (USAID, 2018).

Besides this, production of building materials and the construction process has moved away from the earlier labour-intensive and highly decentralised process to an increasingly centralised machine-dependent model. This was done in an attempt to make the construction process more efficient. However, this type of production model increases the expenditure on transportation, uses fossil fuel based heavy machinery and is often times less energy efficient and more polluting. The automation has also resulted in the loss of jobs. This decline in employment has also resulted in the loss of skills that traditional masons, carpenters, and other workers possessed (Reddy, 2004).Building materials that form the largest share of a building's lifetime carbon footprint. Studies have found that cement is a key cause of pollution in the world. Manufacturing construction material produces 7% of global carbon dioxide emissions. Brick kilns contribute to up to 20% of global black carbon emissions, alongside steel and iron production. Building construction is also responsible for releasing toxic dust along with producing large amounts of waste generation and water use (Dezem, 2019).

PROPOSED SOLUTION

It is important to invest in buildings that are sustainable not just to build but also to maintain. There are numerous ways in which recycled and environmentally-friendly material can be used for construction. Innovative strides are also being made for the efficient operation of buildings- energy efficiency, solar heating, natural insulation, rainwater harvesting, wastewater treatment, and solid waste management (The Green Building Council, 2019). It is also imperative that all stakeholders involved in the construction process understand the need for and are familiar with environmentally friendly alternatives to conventional building materials and techniques (Kakkar, 2014).

Buildings at COSTFORD in Kerala

TRAINING FOR SUSTAINABLE CONSTRUCTION

THERE IS A NEED FOR A LABOUR FORCE THAT IS TRAINED IN HANDLING THE DEMANDS FOR SUSTAINABLE CONSTRUCTION.

Workers at brick factory: Earth Blocks India in Bangalore

Sustainable construction is the need of the hour and there is a greater push towards it with initiatives by the government and other bodies. In 2007, out of 85 internationally registered projects under LEED NC-USA, 32 were registered in India. LEED is an international body that rates sustainable buildings using several different factors. The number of buildings that have received this rating has been growing steadily and the past decade has seen a significant jump in the demand for sustainable buildings. This is being pushed by concerns about rapid climate change and growing awareness about environmentally friendly alternatives (Tathagat & Dod, 2015). A recent global study projected that the construction industry can reduce the embodied carbon emission by 40% in the next ten years and reach net zero emissions by 2050 (World Green Building Council, 2019).

One of the major hurdles in implementing sustainable building methods is the lack of awareness. The Indian construction industry was largely reluctant in adopting sustainable practices - viewing it as an extra cost instead of an efficient construction method (Reddy, 2004). With no institutional mechanism to skill construction workers, they continue to receive informal training. This poses two key problems: not all workers are able to receive the skills required and there is very little utilisation of new technologies and techniques (Kakkar, 2014).

METHODOLOGY

THIS EXPLORATORY REPORT HAS EMPLOYED THE FOLLOWING RESEARCH METHODS:

Background Research

This forms the essential framework of the report, guiding all other investigations. The focus of the background research has been on understanding the topic at hand and compiling a database of stakeholders. This includes research into sustainable and energy efficient technologies, compiling a list of vendors for sustainable construction materials, and research into existing training programs for workers.

Primary Research

Primary research was conducted by the team in the month of December 2019 for the understanding of the techniques and materials used by different organisations working in sustainable construction. Field visits, in-person and telephonic interviews were conducted as part of primary research with various stakeholders, including architects, manufacturers, construction workers, and residents. These discussions revolved around energy efficient methods used by the organisation, their view about sustainable construction, need of training and skilled workers in the construction of sustainable buildings.

Research team at Earthblocks India factory in Bangalore

ABOUT
SUSTAINABLE BUILDINGS

Exposed bricks in the courtyard: No. 9

WHAT IS A SUSTAINABLE BUILDING?

There are a number of features which can make a building sustainable. These include:

- Efficient use of resources like energy and water
- Increased use of renewable energy like solar energy and wind energy
- Reduction of pollution and waste by enabling of re-use and recycling
- Improved indoor environmental air quality
- Use of non-toxic and sustainable materials
- Consideration of the environment in design, construction and operation
- Consideration of the quality of life of occupants in design, construction and operation
- A design that enables adaptation to a changing environment

A 'green' building can be defined as a building that, in its design, construction, and operation, reduces or eliminates negative impacts, and can create positive impacts on our climate and natural environment. These sustainable buildings preserve natural resources and reduce polluting outputs. Any building can be a green building - a home, an office, a school, a hospital, a community centre, or any other type of structure (Sing & Pandey, 2012).

ABOUT
PHASES OF SUSTAINABLE CONSTRUCTION

For a building to be truly energy efficient, the energy consumption in each phase of a building's life cycle must be achieved. These phases can be broadly categorised under: pre-building phase, building phase, and post building phase. The ways to provide energy efficiency is not only different for each of these phases but it will also differ with factors like function, location, and budget (Module on energy efficiency in buildings, 2009).

Pre-building Phase

This section starts right when the site is being selected. It involves the entire design process and is the most essential part. It is during this phase that care must be taken to maximise the energy efficiency of the building. This will start with determining the position and orientation of the building based on the climatic conditions and proximity to other buildings (Izzet, et al., 2016). The design should be such that the building utilises the sun and wind, ensuring minimum heat gain in warm seasons and maximum in cold. This can be done through using an open plan and proper ventilation channels. Windows reduce the need for artificial lighting while improving daylight.

The selection of materials is a very important part of making a building sustainable. Materials should be selected keeping in mind the location and cost of the building. Out of the total energy consumed during construction, the amount of energy spent on transportation of materials to the site is considerably high. If the construction materials are locally sourced, energy consumption and cost of transportation can be reduced. Another solution can be to use recycled resources to provides a considerable preservation of raw material and energy. Using highly qualified manpower in the manufacturing process will also reduce the energy consumption. Materials that use non-renewable resources and cause excessive pollution during the manufacturing process can also be avoided.

Building Phase

The energy consumption in construction changes according to building systems. Building techniques and equipment consuming less energy should be given preference, while ensuring that no concession is made in the quality of building. Heavy duty vehicles like lifting cranes, concrete pumps, and concrete transit mixers consume high amount of energy. New and innovative construction techniques like rat trap bonds and lattice walls should be the norm. Besides this, proper management of work site will also help in reducing wastage of materials and energy consumption.

Post building phase

According to WBCSD (World Business Council for Sustainable Development) report, 88% of the energy consumed in buildings is spent during usage and maintenance. Once the construction of the structure is completed, energy is used for day to day activities and this can be made sustainable by using energy efficient electrical and plumbing fixtures. LED lights use 75 % less energy than normal lights. HVAC Electronics that are star certified consume 30 to 65 % less energy than non-certified products. Installing solar panels or wind turbines on the roof will reduce the dependency on grid power. Using albedo paints (cool roof coating) will further reduce heating up of the rooms and the need for cooling systems. This can also be done through the construction of roof gardens that reduces the heat absorption. These technologies may have high initial cost but are more efficient in the long run. The Government also provides subsidies for alternative practices like solar panels, LED lights etc.

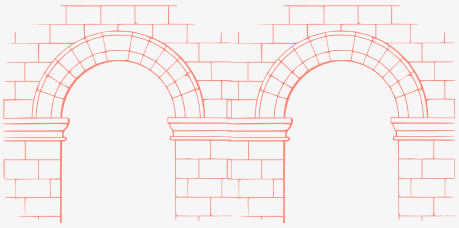
ABOUT
SUSTAINABLE BUILDING MATERIALS

Compressed Earth Blocks (CEB)

Compressed Earth block is made from an appropriate mix of inorganic soil, expansive clay, and aggregate. The mixture is compressed at high pressure to produce blocks. These bricks can be produced on site or on a much larger scale in a factory. The bricks are extremely cost effective and sustainable but do not compromise on strength in any way (Auroville Earth Institute, 2012). Earth Blocks India Factory made using mechanically compressed earth blocksCEBs are manufactured in energy efficient and eco-friendly process. These bricks produced are of accurate dimensions and surface finish and provide better thermal insulation. It is a cost effective technology and does not require external or internal plastering. These bricks are also sound and fire resistant.

Fly-ash Sand Lime Gypsum Bricks

These bricks are made by mixing fly ash with bonding agents like sand or stone dust, hydrated lime sludge lime, gypsum, and even cement. The fly ash, which constitutes over 60% of the brick, is obtained from thermal power plants. Fly ash bricks are made using a hydraulic or vibratory press (Shetkar et al., 2016). Fly ash Sand lime gypsum bricks are eco-friendly as it uses fly ash, which is a waste by-product of thermal power stations. These bricks are more energy efficient compared to traditional burnt clay bricks. These bricks produced are uniform in shape and require less mortar in brickwork and finishing and saves usage of cement mortar. These bricks are lightweight, easy to transport and are durable. They are also extremely cost effective as its main component is a waste product with zero value of its own (Rani & Sikka, 2018).



BRICKS

Brick	Material	Cost (Compared to conventional bricks)	Training Requirement: Production	Training Requirement: Use
Compressed Earth Block	Inorganic Soil, Clay	15-20% Lower	Basic	Basic
Fly-ash Bricks	Fly-ash, Sand, Lime, Gypsum	30% lower	Basic	Basic
Marble Slurry Bricks	Marble slurry, cement, lime	25-30% lower	Basic	Basic
Plastic Bricks	Plastic, bonding agent, polymer	NA	Advanced + Intermediate	Basic + Intermediate

Marble Slurry Bricks

This type of brick is made primarily from marble slurry, a waste by-product that is otherwise a major pollutant. The slurry is used as a fine aggregate in manufacturing bricks by using cement or lime as a binder (Singh et al., 2016). Marble slurry bricks are environment friendly as it involves high volume utilisation of waste. It cuts down cost and time of construction. It has higher strength and load bearing capacity in comparison with regular clay bricks and are fire resistant. These features of marble slurry bricks make it an another option for construction of sustainable buildings.

Plastic bricks

This new innovation takes tonnes of plastic waste littering the environment and converts it into sustainable building materials. The bricks are made by collecting, processing, and compressing plastic into building blocks that can then be used for various purposes (Varier, 2017). Plastic bricks are environment friendly as they are made from polluting waste. These bricks are thinner and lighter than standard bricks. It has excellent heat insulating properties and are strong and durable. These bricks are also cheap and more fuel efficient to manufacture. All these features make it one among the available alternatives for the construction of sustainable buildings.

ABOUT
SUSTAINABLE BUILDING MATERIALS

Micro Concrete Roofing Tile (MCR)

These tiles are a cost effective and sustainable roofing material. MCR tiles are made by vibrating an optimum mix of cement, sand, fine stone aggregate and water on a vibrating table. These tiles can replace traditional thatch and fired clay tiles (Patara, 1992). The tiles are considerably cheaper and highly durable compared to other roofing. MCR is lighter than other roofing tiles and requires less under structure, cutting down consumption and cost. It is easy to install and can be customised. It reduces heat gain and does not make noise during rains, making it ideal for diverse climatic zones. MCR does not contain asbestos fibres, reducing their impact on the environment. The tiles do not need to be fired and hence the impact on the environment is further reduced (Jayasinghhe et al., 2006).

Ferrocement Roofing Channel

These are prefabricated cylindrical shell units that can be used as roofing channels. The length of these channels can be adjusted to the length of the room to be roofed. It is made from ferrocement which is a is a highly versatile form of reinforced cement concrete possessing unique properties of strength and durability (Sriraman, 1996). Ferrocement roofing channels have low installation time and cost as shuttering is not required. This technique is both more cost effective and more energy efficient compared to traditional roofing. These roofs are lightweight and slender, reducing the dead load on walls. It has high strength to weight ratio makes it suitable for intermediate flooring as well.

ROOFING

Roofing	Material	Cost (Compared to conventional roofing)	Training Requirement: Production	Training Requirement: Use
Micro Concrete Roofing Tile	Cement, sand, fine stone aggregate	NA	Basic	Basic
Ferrocement Roofing Channel	Ferrocement, sand	40% reduced	Basic	Intermediate
Bamboo Roofing Sheets	Bamboo, preservative, brush bond	40% reduced	Basic	Basic

Bamboo Roofing Sheets

This is an alternate roofing material to galvanised iron and asbestos corrugated sheets. It is made out of bamboo mats treated with preservatives and bonded with polymer and brush bond coating.Bamboo roofing sheets are environmental friendly and natural roofing alternative. It has high energy efficient production and installation. It is light but high in strength and resilience. These sheets are lightweight and waterproof and termite proof. It has excellent thermal insulation properties. It is also an income generating activity for local population in bamboo growing regions (D.N., 2015).

ABOUT
SUSTAINABLE BUILDING MATERIALS

Bamboo Flooring

Bamboo flooring gives a wood like finish but is considerably more sustainable. This flooring is made from Bamboo which is a natural vegetation that matures in three to five years, compared to the twenty years trees can take. It is durable, easy to maintain and to install. The material is also considerably cheaper and the cost can be further reduced if the bamboo is sourced locally and the manufacturing plant is close to the construction site.

Reclaimed Hardwood

Instead of using traditional hardwood floors, more eco-friendly options can be considered to combat deforestation concerns. Reclaimed wood is an ideal option as it reuses existing wood from discarded furniture, flooring, doors, or any other wood products (Meghna, 2019). The manufacture of this flooring provides an employment opportunity for unskilled workers. The installation process is similar to that of other hardwood floors and the same type of training is required.

Glass Tiles

These tiles are made from recycled glass bottles and are extremely energy efficient. It is a renewable source and specially suited for bathroom and kitchen walls. It is non-absorbent and resistant to mold in damp environments. It is easy to maintain and does not stain. Because glass comes in many different colours, it can be incorporated into any design. The cost of the product is also less as it reuses waste. Experience is required to work with these tiles and masons will need a little training.

WALLS AND PARTITIONS

Product	Material	Cost (Compared to conventional)	Training Requirement: Production	Training Requirement: Use
Ferro Cement Wall Panels	Cement, aggregate, steel	15-18% lower	Basic	Intermediate - Advanced
Bamboo Mat boards	Bamboo mats, preservatives, polymer	40% lower	Basic	Basic

Flooring

Flooring	Material	Cost (Compared to conventional)	Training Requirement: Production	Training Requirement: Use
Bamboo Flooring	Bamboo, bond, preservative	15-18% lower	Basic	Basic
Reclaimed Hardwood	Wood, bond, preservative	10-20% lower	Intermediate	Basic
Glass tiles	Glass	Upto 30% lower	Advanced	Intermediate

Ferro Cement Wall Panels

These are a cost-effective product used for walling, particularly during speedy construction projects. It is made of closely spaced, multiple layers of mesh or fine rods completely embedded in cement mortar. Ferro cement wall panels are cost effective and energy efficient technology. It has dimensional regularity in shape and size. It contributes to the reduction in construction and finishing time. Components for these ferro cement wall panels can be recycled from construction sites (Selvamani et al., 2014).

Bamboo Mat Boards

These boards can be used as partitions, false ceilings, shutters, and anywhere else to replace commercial plywood. They are made out of bamboo mats treated with preservatives and bonded with polymer and brush bond coating. Bamboo mat boards used for partitions, ceilings etc are energy efficient and environmentally friendly technology. It functions like plywood in terms of versatility, strength, and durability. It is resistant to water, fungi, termites and other insects (Ipriti, 2001)..

ABOUT
SUSTAINABLE BUILDING MATERIALS

Low VOC Paints

Low VOC paints have reduced amounts of volatile organic compounds. These paints are much better suited for the indoors and provide for a healthier environment. No expertise is required to use this paint and painters can pick it up with brief training.

Zero VOC Paints

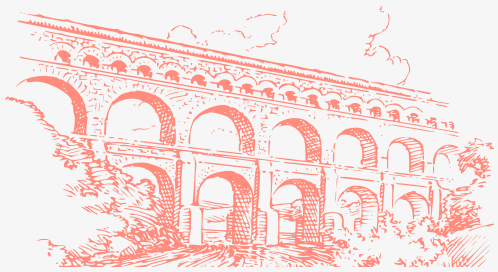
Paints with no VOCs have no volatile organic compounds in them and do not contain any harmful chemicals. Application process is similar to normal paints and painters can be trained very easily.

Natural Paints

These paints are made using natural substances and have no harmful compounds in them. They are made by mixing organic base solvents with natural tints derived from things like flowers, fruits, vegetables, and chalk. However, they are considerably harder to use and require ample understanding and training (Sorrel, 2009).

PLASTERS

Product	Material	Cost (Compared to conventional option)	Training Requirement: Production	Training Requirement: Use
Clay Plasters	Mud + additives	60% lower	Intermediate - Advanced	Basic
Lime Plasters	Lime + additives	NA	Intermediate - Advanced	Basic



PAINTS

Product	Material	Cost (Compared to conventional option)	Training Requirement: Production	Training Requirement: Use
Low VOC Paints	NA	Upto 30% higher	Advanced	Basic
Zero VOC Paints	NA	Upto 50% higher	Advanced	Basic
Natural Paints	Organic base natural tints	NA	Intermediate	Intermediate

Clay Plasters

Mud-based plasters often use mud in combination with other natural materials such as wheat straw or cow dung, or with mineral additives such as bitumen, to improve the basic qualities of the earth by acting as stabilisers, hardeners, and waterproofers. Even without additives, however, mud plasters and renders can give excellent results provided they are made and applied with skill and care, and maintained regularly. Clay plasters are natural and environmentally friendly method; the plaster is less toxic and highly energy efficient. These plasters are cost effective, do not require expensive and elaborate tools and can be easily repaired and touched up. However, it requires skilled craftsmanship for good finishing (Roberts, 2017).

Lime Plasters

This is a type of plaster that uses Lime as a binding substance and is mixed with clay, sand, water, and even cement in some cases. This mixture can be reinforced with natural additive fibres like rice husk, jute pieces, etc. Lime will set with time due to carbonation and makes a plaster layer as tough and solid as limestone. This plaster is less toxic and environmentally friendly. Lime plaster sets up to a solid mass that is durable yet relatively flexible. The plaster is less affected by water and will not soften or dissolve like drywall and earthen or gypsum plaster. Plaster made from hydrated lime is less brittle and less prone to cracking, requiring no expansion joints. It requires trained artisan to provide the perfect finishing (Roberts, 2017).

ABOUT
SUSTAINABLE BUILDING TECHNIQUE AND TECHNOLOGY

Rat trap bonds

This is a type of wall brick masonry bond in which bricks are laid on edge. This leaves the wall with an internal cavity bridged by the rowlock and cuts the consumption of raw materials like brick, mortar and cement. This technique reduces the consumption of bricks by 25%. It also reduces mortar consumption. Total load on foundation is 80% less than that of a solid wall and it has excellent insulation and strength. This is one of the most common techniques used in the construction of sustainable buildings (SEP, 2011).

Rainwater harvesting system

Morey et al., (2016) alludes rooftop rainwater harvesting systems at homes as the most suitable way to meet demand for increasing water supply for different purposes. Rooftop rainwater harvesting system collects water in the catchment area and is then filtered and stored in reservoirs for further uses. According to Morey et al., the biggest advantage is less reliance on other sources for water and is reduced water consumption bills. Roof top rainwater harvesting systems are easy to construct and manage. Cost of rainwater harvesting system varies depending upon the type, area of catchment etc.The major advantage is that it is less expensive and provides high quality water. Reusing kitchen water for gardening purposes are another simple method that can be followed in every home. Costford organization has also experimented their buildings with sloping roofs and water tanks connected to roofs that helps in recharging the reservoir tank with water from the roof. Advantages of Rainwater harvesting system include: Reduced water consumption bills, low cost, and superior quality of water.

A rainwater harvesting system installed at Costford in Kerala

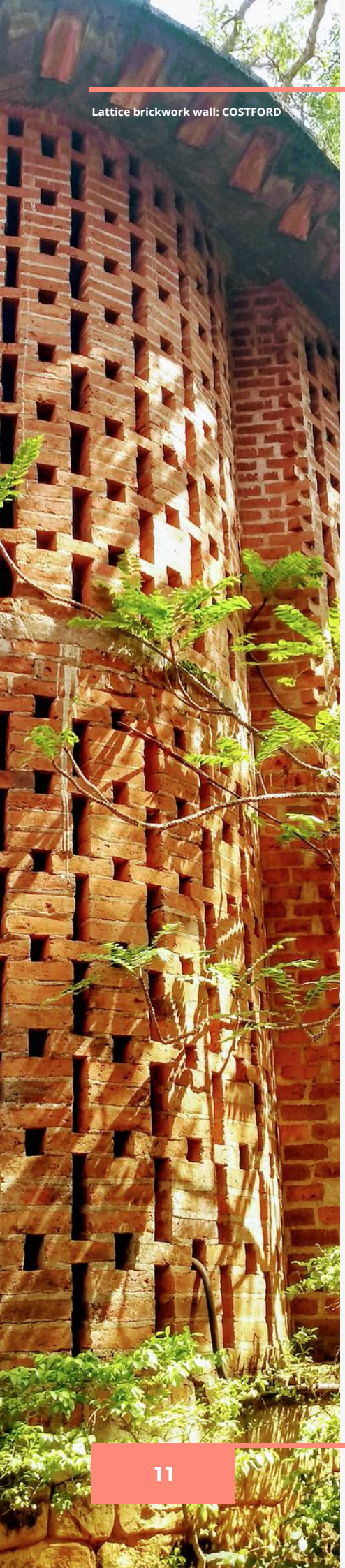
Solar Panels

Photovoltaic solar panels are used in sustainable homes to generate electricity. These panels are usually installed on the roof where they absorb sunlight as a source of energy to generate direct current electricity. This electricity can then be stored in batteries and converted using an inverter to power household appliances and electric fixtures. These panels are also used in solar water heating systems. Solar energy is a renewable, clean, and free source of energy. The use of this technology greatly reduces electricity cost and the government even provides subsidies to all households that use this technology (Team ProductLine, 2019).

Energy Efficient Lighting

About one-fifth of India's electricity consumption is through lighting. A large part of this is wasted through inefficient light bulbs and tube lights. More than 400 million light points in India still use incandescent bulbs. If these were to be replaced with more energy efficient options like CFLs, it would lead to a reduction of over 10,000 MW in electricity consumption (Doola, 2009). While these lights are slightly more expensive, they greatly reduce electricity cost. The government even provides incentives and subsidies for the promotion of their use.

A solar water heating system at a residence in Bangalore



Lattice brickwork wall: COSTFORD

TRAINING OPPORTUNITIES

A TRAINED LABOUR FORCE IS KEY FOR BOTH CREATING AND SUSTAINING A DEMAND FOR SUSTAINABLE BUILDING MATERIALS AND METHODS. AFTER EVALUATION OF THE VARIOUS SUSTAINABLE BUILDING MATERIALS AND TECHNIQUES, THE FOLLOWING TRAINING OPPORTUNITIES HAVE BEEN IDENTIFIED:

MASONS

Compressed Earth Block
Training can be provided on both manufacturing and use of CEBs. For the manufacturing of bricks, basic knowledge on the working and handling of CEB Press is required. The building technique differs only slightly from that used with regular bricks and can be easily adapted with brief training. Additionally, training can also include the use of other eco-friendly building materials like natural mortar mixes and plasters.

Building with eco friendly bricks
Training opportunities are available on the use of different bricks like fly ash bricks and marble slurry bricks. The training will include knowledge on the different types of bricks and practice on working with different types of bricks.

Micro Concrete Roofing Tile
Training would include both manufacture and use of MCR Tiles. For the manufacturing of the tiles, basic training the machinery is required. The building technique differs only slightly from that used with regular tiles and can be easily adapted with brief training. Additionally, training can also include the use of other eco-friendly building materials like natural mortar mixes and under structures.

Ferrocement Roofing Channel
The training can include both manufacture and installation of the roofing channels. These roofing channels require a high level of expertise to install. The training will need to be provided by experts and cover all relevant knowledge: mould preparation, steel and mesh preparation, casting procedure, demoulding procedure, installation procedure, and curing procedure.

Bamboo roofing sheets
Basic training will help construction workers in mastering the manufacture and installation process. The manufacturing process also provides a great opportunity for the employment of people with little skill and only brief training. The mats function similarly to traditional roofing methods and masons can adapt with brief training . There are several organisations that provide training in this area.

Rat trap bond
This is a labour intensive technology requiring skilled labour and extra care. Masons need ample training and familiarity with the bricks, mortar, and placement technique. There are several organisations that provide training in this area.

TRAINING OPPORTUNITIES

CARPENTERS

Use of Bamboo
Basic training will help construction workers in mastering the manufacture and installation process. The manufacturing process also provides a great opportunity for the employment of people with little skill and only brief training. Bamboo mat boards function similarly to plywood and workers can adapt with brief training. There are several organisations that provide training in this area.

PAINTERS AND PLASTERERS

Use of natural plasters
Training program will include the different materials and techniques involved in working with natural plasters. While these are innumerable in number, they can be tailored to fit the existing skill sets and the geography of operation. There are several organisations that provide training in this area.

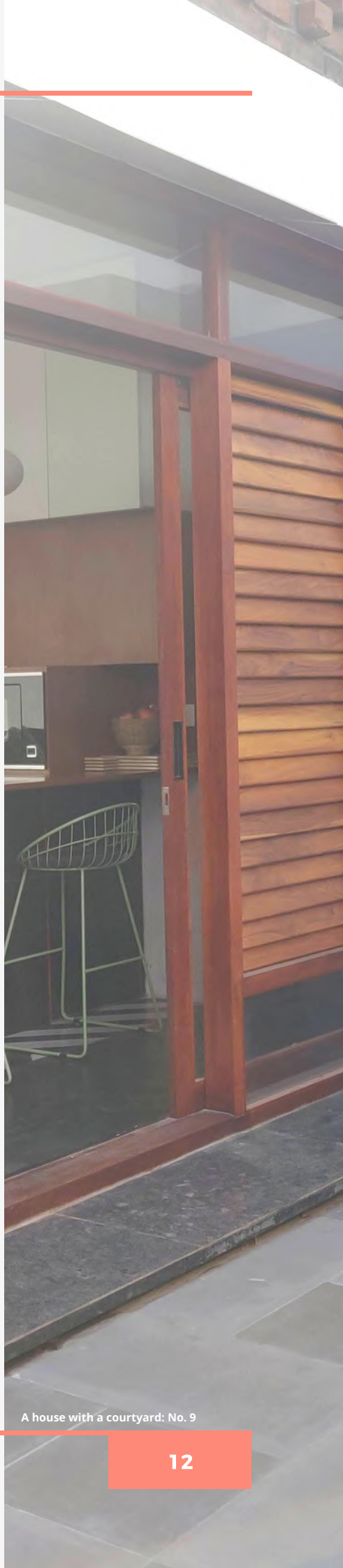
Use of natural paints
Natural paints are not just cost effective and eco-friendly alternatives to regular paints but are also safer to manufacture and use. The non-toxic alternatives require basic training to be adapted by painters. There are several organisations that provide training in this area.

Plumbers

Installation of Rainwater Harvesting System
With the government mandating rainwater harvesting systems in most cities, it becomes essential to be familiar with the technique. The installation process is fairly simple and only brief training will be required. The training will have to cover various aspects like installation of different filtration systems, roof requirements, piping, and even maintenance. Along with this, the training session can also include information on installing other sustainable fixtures like low water use taps and flushes.

Electricians

Installation of Solar Panels and Generators
Electricians can be trained to install a solar power generating unit. This will include knowledge on installation of solar panels, batteries, and inverters. This training can also include brief knowledge other energy efficient light fixtures like CFLs.



A house with a courtyard: No. 9

Factory from Compressed Earth Blocks: Earth Blocks India in Bangalore

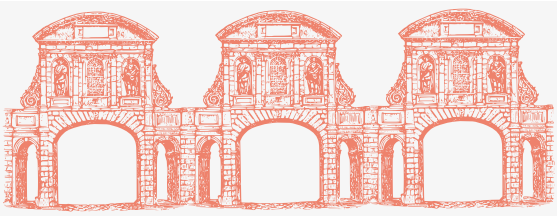
TRAINING PROVIDERS

Compressed Earth Bricks

Name of the Institute	Training Provided On/Specialization	Contact/Address
- Auroville Earth Institute:	Several training programs of short duration that covers manufacturing, building, and designing with CEBS	Pondicherry, (0) 413 - 262 3330 / 262 3064, training@earth-auroville.com
VSBK/CESEF Project	Extensive training program covering multiple sustainable building materials and practices	VSBK Project Nepal Pulchowk, Lalitpur P.O Box 113, Kathmandu, Nepal shashank.pandey@vsbk.org.np
BMTPC - Building Material and Technology Promotion Council:	Training working professionals and workforce on various topics including sustainable construction with earth blocks	Core 5 -A, First Floor , India Habitat Centre, Lodi Road, New Delhi- 110 003, 24638097
DRISHTEE	6 month training program for women in Assam, Bihar, U.P. The training includes a	BSI Rise Tower, H-15, First Floor- 107/108 Sector 63, Noida- 201307 info@drishtee.com
WE RISE homes by NIVASA	Training by NIVASA an architectural ngo in Bangalore that aims to build community driven sustainable housing for marginalised community. They provide trainings on making bricks using silt deposited in nearby lakes	The Millenia Tower- B Level 12-14 No.1&2 Murphy Road Ulsoor Bengaluru 560008

Eco friendly bricks

Name of the Institute	Training Provided On/Specialization	Contact/Address
Van Sampada	training and help in finding employment in the fly ash brick industry	Nagpur 9423110814
TARA (The Society for Technology & Action for Rural Advancement)	Training and capacity building in CEBs, fly ash bricks	B-32, Tara Crescent, Qutub Institutional Area New Delhi - 110 016, India mailto:tara@devalt.org
BMTPC - Building Material and Technology Promotion Council	Training working professionals and workforce on various topics including sustainable construction with hollow cement bricks, CEBs, fly ash bricks	Core 5 -A, First Floor , India Habitat Centre, Lodi Road, New Delhi- 110 003, 24638097
SCJ - Skill Council for Green Jobs	training focused on skill building and use of eco-friendly building materials including bricks	3rd Floor, CBIP Building, Malcha Marg, Chanakyapuri, New Delhi - 110021 info@sscgj.in



Ferrocement roofing channel

Name of the Institute	Training Provided On/Specialization	Contact/Address
BMTPC - Building Material and Technology Promotion Council	Training working professionals and workforce on the manufacture and installation of ferrocement roofing channels	Core 5 -A, First Floor , India Habitat Centre, Lodi Road, New Delhi- 110 003, 24638097
Auroville Earth Institute	A week long course covering various applications of ferrocement are taught through lectures, presentations and predominantly hands-on demonstrations	Pondicherry, (0) 413 - 262 3330 / 262 3064, training@earth-auroville.com

Concrete roofing tiles

Name of the Institute	Training Provided On/Specialization	Contact/Address
SKAT - Swiss Centre for Appropriate Technology:	designed training packages for effective dissemination of manufacturing and use of alternative roofing technology	Skat Consulting Ltd. Vadianstrasse 42 CH-9000 St.Gallen Switzerland info@skat.ch
TARA - The Society for Technology & Action for Rural Advancement:	Training and capacity building in the manufacture and use of micro concrete roofing	World Headquarters: B-32, Tara Crescent, Qutub Institutional Area New Delhi - 110 016, India mailto:tara@devalt.org
BMTPC - Building Material and Technology Promotion Council	Training working professionals and workforce on the use of micro concrete roofing tiles	Core 5 -A, First Floor , India Habitat Centre, Lodi Road, New Delhi- 110 003, 24638097

Rat trap bond

Name of the Institute	Training Provided On/Specialization	Contact/Address
PMAY - Pradhan Mantri Awaas Yojna	one day training on rat trap brick toe wall	Multiple locations
BMTPC - Building Material and Technology Promotion Council	Training working professionals and workforce on rat trap bond method of masonry	Core 5 -A, First Floor , India Habitat Centre, Lodi Road, New Delhi- 110 003, 24638097
PSG Institute of Technology and Applied Research	Two day Hands on Training on brick masonry in New Delhi	Avinashi Road, Neelambur Coimbatore - 641 062 Tamilnadu. 0422 3933666

Bamboo sheets and other bamboo products

Name of the Institute	Training Provided On/Specialization	Contact/Address
DRISHTEE	6 month training program for women in Assam, Bihar, U.P. The training includes a module on use of indigenously grown bamboo	BSI Rise Tower, H-15, First Floor- 107/108 Sector 63, Noida- 201307 info@drishtee.com
SCJ - Skill Council for Green Jobs	training focused on skill building and use of eco-friendly building materials like bamboo	3rd Floor, CBIP Building, Malcha Marg, Chanakyapuri, New Delhi - 110021 info@sscgj.in
IPIRTI - Indian Plywood Industries Research Institute	Research and training including Bamboo primary processing and Mat making, installation of bamboo roofs etc	Post Bag No.2273, HMT Link Road OFF Tumkur Road, Yeshwanthpur, Bengaluru - 560022 director@ipirti.gov.in
PMAY - Pradhan Mantri Awaas Yojna	Training on procurement and treatment of bamboo, making of trusses	Multiple locations

Walls with natural plasters and paints

Natural plasters

Name of the Institute	Training Provided On/Specialization	Contact/Address
Made in Earth	Architecture studio in Bangalore that holds regular workshops on natural plasters and working with clay for interiors	Nagarabhavi Circle, Jyothi Nagar, Bengaluru, Karnataka 560072 9986704355

Natural paints

Name of the Institute	Training Provided On/Specialization	Contact/Address
Indian Paint Association	A training program on paint and paint application for painting supervisors, applicators and painters	The Indian Paint Association Secretariat Affiliated with CII 6, Netaji Subhas Road, Kolkata 700 001 9133 2231 5571
Berger Paints	Training under Green Horizon- an eco-friendly painting option	Berger House, 129 Park Street, Kolkata 700017 91 33 2229 9724
Kamdhenu Paints	Training on green paints in association with Graphenstone	2nd Floor, Tower A, Building No. 9, DLF Cyber City, Phase 3, Gurgaon 122002 (Haryana)

Walls with a light coat of natural plaster

DETAIL OF MATERIALS AND TECHNIQUES

Technique/Process	Cost	Labour Requirement
Compressed Earth Blocks	- 15-20% less than conventional regular fired bricks (Cost details CSEB produced with an AURAM press in July 2012) - Reduced labour cost - Reduced raw material co - Cheap equipment	- CEB allow unskilled and unemployed people to learn a skill, get a job and rise in the social values - Produced locally by semi-skilled and unskilled people - Training required to understand product and operate production machinery - Labour requirement for use in construction is same as that of conventional bricks
Fly-ash lime gypsum brick	- The cost of fly ash brick is approximately 30% lower than clay brick (Rani & Sikka, 2018) - Transportation cost can be cut as the bricks are lightweight and in case of bulk supply the plant can be installed at site to further minimize the cost - Cost of cement mortar is reduced	- The manufacturing of bricks requires employment of both skilled and unskilled labourers - With brief training, unskilled and unemployed people can be employed - Masons will also require brief training to alter building methods
Marble Slurry Bricks	- Lower cost of production because chief raw material is industry waste and has little monetary value - Cuts down on mortar use by 28% - Cuts down labour cost by 30%	- With brief training, unskilled and unemployed people can be employed - Masons will also require brief training to alter building methods
Plastic Bricks	- The material cost is extremely low - Cheaper and lighter bricks that are easier to transport.	- Manufacturing is done in industrial factories and requires a certain level of expertise - Masons need to be trained in order to adopt the new technology.

Micro concrete roofing tiles	- The manufacturing process cuts down on both material cost and production time - Labour cost is also reduced with a cut in construction and finishing time - Cost of understructure is reduced - Decentralized production process	- The production process and machine is economical and requires brief training to master - The manufacturing can be easily decentralized - Masons can adapt their skills to MCR with minimum training
Ferrocement Roofing Channels	- Reduces upto 40% cost in comparison with R.C.C roof - Reduces labour cost by saving 3 weeks of construction time	- Manufacturing process is fairly simple and little training is required - Installation process requires expertise and relevant training
Bamboo roofing sheets	- Extremely affordable and costs upto 40% less than other similar roofing materials	- Manufacturing process can employee a large number of people with little skill and only brief training is required - The mats function similarly to traditional roofing methods and masons can adapt with brief training
Clay Plasters	- Raw material used is natural, cheap, and locally available - The plastering cost can be cut by over 60%	- This is a labour intensive technology - The method requires workers with adequate knowledge about the composition and the application of mud plasters
Lime plasters	- The plaster is made from inexpensive materials and hence reduces the overall cost of the building	- This is a labour intensive technology - The method requires workers with adequate knowledge about the composition and the application of mud plasters
Rat trap bond	- Extremely cost effective as the raw material cost is reduced considerably	- Labour intensive technology - Skilled labor and extra care are needed to design this bond

DETAIL OF MATERIAL COST

Name	Product	Location	Contact	COST	
				Price	Specifications (one unit)
Earth Blocks India	Compressed Earth Bricks	Bangalore	9886636986	Rs 28 per unit **(Min order: 1500 units)**	300 X 150 X 90 mm
Shankala Interlocq Briques	Interlocking Compressed Earth Blocks	Hosur, Tamil Nadu	9095796662	Rs 26/Piece	6"x10"x5" Wlh (8"X10"X5") Wlh
Aureka	CEB Press Auram Press 3000 Auram Press 4000	Auroville, Villupuram	4132622278	Rs 16,450 to Rs1,67,300 per machine	125 strokes per hour 400 strokes Per hour according to the speed of the operator
Sri Banashankramma Interlocking Block	Compressed Earth Bricks Earth Blocks Compressed Interlocking Earth Block	Bengaluru	8048920501	Rs 28 / Block Rs 18 / Block Rs 28 / Block	12x6x6 4x9x7
Magic Zone International Private Limited	Fly Ash Bricks Fly Ash Bricks Fly Ash Bricks	Rajarhat, Kolkata, West Bengal Nagpur Chandrapur	8046065595	Rs6/piece	9x4x3
Tetron Merchandise Pvt Ltd	Gray Fly Ash Blocks for Side Walls	Bowbazar, Kolkata, West Bengal	8042955194	Rs 6.25/Piece **(Min order: 4500 Piece)**	
Rajratan Pvt Ltd	Rectangular Plastic Brick Pallet	Siyaganj, Indore, Madhya Pradesh	8048105315	Rs240/piece	12,18,21,25 MM
Nasa Industries	Rectangular Recycled Plastic Brick Pallet, Capacity: 200 Ton	Sardar Nagar, Morbi, Rajkot, Gujarat	8046056094	Rs 70/Square Feet	
Bansidhar Products	Rectangular Recycled Plastic Bricks Pallets	Sardar Nagar, Morbi, Rajkot, Gujarat	8048838152	Rs 80/Square Feet	
SAI PRASAD LED AND SOLAR SYSTEMS	Solar heater	Nagpur	8048974465	Rs 14,500/Piece	
Arin Energy	Solar Water Heater 300 LPD	Nagpur	7971272547	Rs 30,000/Unit	300 LPD
Powertrac	Solar Water Heater	Vayusena Nagar, Nagpur, Maharashtra	8048429735	Rs 13,000/Piece	00 lpd, 200 lpd, 200 - 300 lpd, 300 - 400 lpd, 500 lpd, more than 500 lpd
Green Life Solution Private Limited	Solar Heater	Pratap Nagar, Nagpur, Maharashtra	8048934890	Rs 16,200/Watt **(Min order 10 watts)**	
Toyam Industries Pvt Ltd	Water Purification For Drinking Borewell Water Treatment Plant	Lulla Nagar, Pune, Maharashtra	8048024412	Rs 50,000/Unit	**Capacity Inlet Flow Rate** 500 m3/hour
Red Circle Industries	SS And FRP Semi-Automatic Effluent Treatment System, Effluent Treatment Plant	Manewada, Nagpur, Maharashtra	8049440591	Rs 8 Lakh/unit	2.4-6.4 Litre/H
RO Plant Solutions	Borewell Water ISI Mineral Water Plant, ISO, Jar Filling Machine	Wardha Road, Nagpur, Maharashtra	8048569334	Rs 4.25 Lakh/Unit	**Capacity Inlet Flow Rate (cubic meter/hour)** 2000 L/Hour
Keten RO Solutions	Stainless Steel Industrial Water Purification Plant	Vayusena Nagar, Nagpur, Maharashtra	8048566649	Rs 4.5 Lakh/Unit	500-1000 LPH
Shri Vardhan sTEEL	Red Steel / Stainless Steel Corrugated Roofing Sheets	Lakadganj, Nagpur, Maharashtra	8048881565	Rs 64/Kilogram	
Evershine Roofing and Cladding	Corrugated Roofing Sheets	Bajaj Nagar, Nagpur, Maharashtra	8048972173	Rs 400/Square Meter	0.35 - 0.80 mm **(thickness)**
Jain Profile and Slitting Industries	Steel Jindal Corrugated Roofing Sheets, for Residential	Bagadganj, Nagpur, Maharashtra	8048956874	Rs 70/ square meter	
Burhani Trading Company	Jain Biogas Plant with Fabric Digester, Usage: Industrial	Gandhibagh, Nagpur, Maharashtra	8042952049	Rs 45,000/Box	**Waste input:** 0-100 kg, 100-500 kg, 500-1000 kg
Urja Bio System Pvt Ltd	Semi-Automatic Floating Dome Biogas Plant for Industrial	Shivaji Nagar, Pune, Maharashtra	8048712503	Rs 40 Lakh/Piece	5-10 ton, 1-50 Ton

LIST OF VENDORS

Name	Product	Location	Contact
BMTPC	Sustaible building methods	New Delhi	011-24636705
Earth Blocks India	Compressed Earth Bricks	Bangalore	9886636986
Aureka	CEB Press	Auroville	4132622278
TARA	Multiple	New Delhi	26545100
Van Sampada	Fly Ash Bricks	Nagpur	9423110814
Panchtarika Ash Brick Industry	Fly Ash Bricks	Nagpur	
Mahila Ash Industry	Fly Ash Bricks	Chandrapur	
Jai Balajee Enterprises	Fly Ash Bricks	Rourkela	
GLT Enterprises	Fly Ash Bricks	New Delhi	9953362622
Eco Vision Industries	Fly Ash Bricks	Noida, Delhi	8447570282
SR Windows and Glass Solutions	Fly Ash Bricks	Noida, Delhi	8587900505
V K Enterprises	Fly Ash Bricks	Guraon, Delhi	9643007698
Aparna Enterprises Limited	Fly Ash Bricks	Hyderabad	8377809349
Affa Tile Company	Fly Ash Bricks	Chennai	8377802185
Techno Design	Fly Ash Bricks	Chennai	8588832165
ABN Enterprise	Fly Ash Bricks	Kolkata	8588832343
Marshall Corporation Limited	Fly Ash Bricks	Kolkata	9953362698
Aster Enterprise	Fly Ash Bricks	Kochi	8588800787
Dev Infratech	Fly Ash Bricks	Vadodra	9582599487
Metco Blocks Mg. Co.	Fly Ash Bricks	Mumbai	8377808662
Bhoomi Trading Corporation	Fly Ash Bricks	Mumbai	8376806063
Mohta Cement Pvt. Ltd.	Fly Ash Bricks	Dhar	9953354394
Pooja Enterprise	Fly Ash Bricks	Pune	8376807223
Allied Concrete Works	Fly Ash Bricks	Mumbai	8587096799
Shreeji Flyash Bricks	Fly Ash Bricks	Vadodra	8586979384
SRG Infratech	Fly Ash Bricks	Jaipur	9873117160
Sheetal Pipes	Fly Ash Bricks	Nagpur	8377809299
Shri Sai Pavers	Fly Ash Bricks	Ludhiana	8588859155
Soanli International	Fly Ash Bricks	Hooghly	9953363063
Teraco Tiles	Fly Ash Bricks	Bengaluru	9643007025
Balaji Cement Products	Fly Ash Bricks	Rajkot	8376809237
Mrinmayee	Stabilized Mud Bricks	Bangalore	080 26582970
Tab India	Marble slurry Bricks	Jaipur	91 141 2744500
Bamboo House India	Plastic Bricks	Hyderabad	
Bamboo House India	Bamboo Housing	Hyderabad	
Earth Blocks India	Compressed Earth blocks	Bengaluru	9845500996
Sulabh International Social service organisation	Biogas	New Delhi	25057748
Quantum Green	Biogas	Bengaluru	8095619619
Swaraj Equipments	Biogas	Chennai	
MSA Bio energy	Biogas	Gujarat	8061882880
Sundaram Fabrications	Biogas	Salem	0427-2313200
Arjun energy corporation	Biogas	Salem	98434 80265
Benchmark engineers and consultants	Biogas	Coimbatore	
Energy management solution of Inida	Biogas Biogas	Chennai	7010435068
Fine Soft Technologies	Biogas	Coimbatore	095858 61893
Kaveish Bioenergy Private Ltd	Biogas	Pondicherry	080-43053125
Dheethya green energy	Biogas	Chennai	044-28133648
Promoters of environmental technology & Energy resources	Biogas	Chennai	044-25550423
B sustain energy projects	Biogas	Arumabakkam	044-23630788
Fine Soft Technologies	Water treatment	Coimbatore	095858 61893
Promoters of environmental technology & Energy resources	Water treatment	Chennai	044-25550423
Promoters of environmental technology & Energy resources	Solar heater and lights	Chennai	044-25550424
Inter solar	Solar heater	Mumbai	022-24128480
Racold solar water heating system	Solar heater	Bengaluru	080- 65598222
Tata power solar systems	Solar heater	Bengaluru	98450 31532
Emvee	Solar heater	Bengaluru	096861 80706
Kotak Urja	Solar heater	Bengaluru	080-48522934
Photon energy systems	solar energy	Thrissur	0487-2331141
Vikram Solar	Solar energy	Bengaluru	080-23580264
AUROVILLE BUILDING CENTRE(AVBC / EARTH UNIT)	FERROCEMENT CHANNELS	Auroshilpam, Auroville - 605 101Tamil Nadu, INDIA	91 (0)413-622277 / 622168
BMPTC	FERROCEMENT CHANNELS Corrugated bamboo roofing	New Delhi	011-24636705

CONCLUSION

Designing an energy efficient building is possible with a multidisciplinary study of different stages of the building life. This starts from the idea of constructing a building and includes the practices and materials used during construction phase along with the technologies required to make the building energy efficient once it starts being used. While environment friendly practices and materials is important, the quality, cost and durability of the structure should not be compromised.

The background research and interviews with industry experts has made one thing clear: there is a dearth of labour force that is skilled and willing to take up the challenges of sustainable buildings. The harmful impact that conventional construction methods is quite important and the demand for alternative green methods is on the rise. Widespread use of sustainable technology is only possible if the workers are aware about efficiently handling natural resources. With a dearth of workers who are skilled in understanding and working with sustainable alternatives, a nation-wide program on sustainable construction will not only help create a competent workforce that will be capable of handling the demands of the future but will also contribute to a cleaner and greener environment.

List of Interviews:

- Architect Basanth from Basanth Consultants
- Megha Nanaiah and Shravan Pradeep from Enviarch Studio
- Prof. Yoganandan from Mrinmayee consultants
- Architect Devapriyan from COSTFORD
- Debashish and Esha Sahoo- Residents of Bangalore
- Indrani and Sunil Kumar- Residents of Bangalore
- Mr. Chokalingam- Resident of Bangalore
- Ranjith Reddy from Earth Blocks India

List of Stakeholders Gathered Data from:

- Housing and Urban Development Corporation Ltd.
- Ministry of Drinking Water and Sanitation
- Ministry of Housing and Urban Affairs
- Ministry of Rural Development
- National Building Construction Corporation (NBCC) Ltd.
- Industry Association
- Building Material and Technology Promotion Council
- Confederation of Real Estate
- Developers Associations of India
- National Institute of Urban Affairs
- National Real Estate Development Council
- Zed Earth
- Total Environment Homes
- Earth Soul
- We Rise Homes by Gramantara and Nivasa
- 1ghar.org
- Made in Earth
- Earth Blocks
- SCGJ (Skill Council for Green Jobs)
- Vasudha Foundation
- Seeds organisation
- BMTPC (Building Material and Technology Promotion Council)
- Sohrabji Godrej Green Business Center
- Firm Terra Architects
- Dharmalaya
- De Earth
- Space matters
- Auroville green practices
- ICMQ India
- COSTFORD (Center of Science and Technology for Rural Development)
- Enviarch Studio
- Mrinmayee consultants

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