WISDOM TO BUILD

A COMPENDIUM OF LOCALLY EVOLVED MATERIALS AND TECHNIQUES FOR SUSTAINABLE SELF-BUILT HOUSING

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Chapter 1: Introduction

Self-constructed housing is of critical importance in India as it is the principal source of housing supply in urban and rural India. Yet, this sub-sector of housing is often ignored and overlooked. That needs to change in this climate challenged world.

The material and energy demand of the building construction sector is among the highest. Therefore, self-constructed housing will also have to be part of the solution. This will require a strategic and guidance framework for choosing materials, architectural designs and techniques to reduce the environmental and carbon footprint of the housing structures.

As much as 60 per cent of the affordable housing sanctioned under Pradhan Mantri Awaas Yojana - Urban (PMAY-U) is self-constructed by beneficiaries under the beneficiary-led construction vertical. Similarly, the PMAY-Grameen scheme for rural and peri-urban areas involves 100 per cent self-construction. This segment is largely run by the informal construction industry which is entrenched in conventional concrete materials and techniques that are carbon intensive with high environmental footprint. They are also devoid of strategies to improve adaptive thermal comfort. Yet India's Cooling Action Plan, 2019 has mandated thermal comfort for all. This needs to be addressed.

While policies are evolving rapidly to set benchmarks for improving energy efficiency and savings in buildings, higher uptake of renewable energy to offset energy demand in buildings, reducing heat gain through material and walling assembly and cutting down embodied energy of building material in modern institutional buildings and mass housing, there is barely any effort to assess the potential of self-constructed housing. There is no template to influence the housing of billions of individuals, which is being created with support from the government or otherwise.

On the other hand, the multitude of self-constructed housing—especially in peri-urban and rural areas—that has relied on traditional and local building materials and age-old local techniques, is disappearing quickly, and giving way to ill-designed and thermally uncomfortable brick and mortar structures. These have not found adequate policy attention and support to realize their potential for reducing environmental, energy and carbon footprint.

Traditional knowledge on climate appropriate construction technologies and materials, that has evolved within the specific context of diverse ecosystems, dominates local housing. There is no strategy to assess the potential of integrating this knowledge with modern structures to reduce material intensity and embodied energy of material, enhance thermal comfort and liveability, and reduce environmental impacts. These materials and techniques include wattle and daub, cob-based walls, stone-based walls (random rubble), Bhunga roof, Kathkuni and Dhajji Diwari structures, and an array of walling and roofing technologies that utilize local materials and local skills to construct houses. All of this is under tremendous pressure.

Self-constructed housing allows more flexible choices of material, techniques and design to retain and reinvent traditional and locally available materials and locally evolved techniques within a specific climatic context. It is possible to combine these with contemporary materials and techniques of self-constructed housing to reduce material and carbon intensity of the structures. The local know-how and materials can provide more efficient ways of resisting climatic stress and even extreme weather events like cyclones and earthquakes. Such technologies are also circular in nature as they utilize locally available materials and generate less waste.

Even though several progressive architects in different ecosystems have begun to experiment with the hybrid approach of integrating contemporary and traditional systems, policies have shied away from taking this on board. On the contrary, housing policies and associated subsidy structures and incentives are tied with the construction of only "pucca" houses as opposed to "kutcha" houses that club and subsume all traditional techniques and materials. Thus, a range of sustainable materials and techniques, that can be a part of the solution to energy and carbon intensive built structures, are getting disqualified and discarded.

This is happening even as there are concerns around high embodied energy of most contemporary materials and use of steel in building construction that increases carbon intensity of the structure. About 40 per cent of all steel used in 2020 was used in building construction.

As a result of this neglect of traditional systems, there is a massive erosion of local knowledge and skills, and also disruption of the ecological base of these materials due to expanding urbanization.

Currently, housing policy is largely focused on material choices for the mass housing sector, institutional buildings and retail. Thus, the Building Material and

Technology Promotion Council (BMTPC), the nodal agency under the Ministry of Housing and Urban Affairs (MoHUA), assesses and documents building materials and alternate technologies including fast-paced and mechanized construction technologies to inform the construction industry. PMAY and its technology sub-mission expedite adoption of these materials. BMTPC has launched several initiatives such as the Global Housing Technology Challenge, Light House Projects, Technology Demonstration Centres, etc. and has developed knowledge resources like the compendiums of emerging technologies for mass housing, among others. These facilitate dissemination of alternate construction materials including prefabricated Sandwich Panel System, Monolithic Concrete Construction using Tunnel Formwork, Precast Concrete Construction System – Precast Components Assembled at Site, Precast Concrete Construction System – 3D Volumetric, Light Gauge Steel Structural System & Pre-engineered Steel Structural System, and PVC Stay In Place Formwork System.

Nascent policy interest in traditional technologies for self-built housing

Though there is no policy mandate for the usage of traditional techniques and materials, the growing interest in traditional technologies for self-built housing is encouraging. This is an opportunity and needs to be leveraged quickly. In fact, recognizing that India's housing sector is dominated by self-construction, BMTPC has recently released two compendiums that include technologies suitable for self-built housing.

For the first time, these compendiums have included traditional technologies that encompass Kath-kuni, Dhajji wall rammed earth, compressed earthen bricks, filler slabs, etc. These can be applied in a widespread area. These are local materials that can help in saving resources while generating employment opportunities for local labour. This is certainly a strategic shift from documenting only industrial materials to including local material.

BMTPC along with CSIR - Central Building Research Institute (CBRI) has developed a compendium that acknowledges that it is unfeasible to continue using conventional brick, mortar and cast-in-situ RCC construction in a world faced with fast depleting natural resources, climate change, greenhouse gas (GHG) emissions and energy scarcity.

The document targets construction of individual houses for low-rise to mid-rise structures. The compendium enlists 66 existing technologies in the categories of:

floor construction technologies, roof construction technologies, wall construction technologies, foundation construction technologies, system level technologies, services and materials, etc. Each system has been explained in detail along with technical specifications, tools and equipment, salient features, cost, sustainability and economic aspects, material requirements, limitations, market linkages, structural drawings/detailing, and relevant standards and references. It also mentions the geo-climatic suitability of these technologies. Unlike most other BMTPC compendiums, traditional technologies such as random rubble masonry, Kath-kuni and Dhaj Diwari find a mention in this one. Another notable addition is of 'bamboo strip walling' which is recognized for its labour intensity and the fact that it provides local employment and improves the economy of the area.

The document however is majorly focused on neo-sustainable and alternate technologies rather than traditional ones. Ferro-cement roofing channels, reinforced brick concrete slabs, ribbed slabs, funiculur shells, compressed earthen blocks and rammed earth masonry are notable technologies that can find application in the self-built housing sector while being more resource efficient than conventional construction practices. The compendium keeps the door open for more technologies to be added as and when developed and verified.

MoHUA organized the Indian Housing Technology Mela (IHTM) as part of the New Urban India Conference and Expo on the 5th and 7th of October 2021 in Lucknow, Uttar Pradesh. The Mela's primary objective was to provide a platform for indigenous and innovative building materials, components, tools and equipment, construction processes and technologies that are sustainable and suitable for low and medium rise (up to G+3 storey) housing construction.

Exhibitors displayed 84 unique technologies/systems/products/materials/machinery at IHTM. After extensive consideration and evaluation, MoHUA established the Technical Evaluation Committee (TEC) which has categorized all technologies, systems, products and materials into four major categories: building systems; products for the building of low-rise dwellings (up to G+3); products/technologies primarily derived from the recycling of industrial/agricultural wastes; and materials, components (doors, windows, construction chemicals, insulation, plumbing, plastering, machinery) and technologies.

A total of 73 technologies have been published in the form of a compendium. The technologies are focussed on single or double storey houses that are self-constructed or constructed with the help of local masons/artisans. The document acknowledges the importance of generating local employment and lists this as a feature under various technologies. The preface to the compendium also admits that conventional brick, mortar and cast-in-situ RCC construction are not sustainable options when faced with challenges such as fast depletion of natural resources, climate change, greenhouse gas emissions, energy scarcity, etc. (see *Table 1: Compendium of indigenous innovative building materials and construction technologies*).

Neo-sustainable technologies that were not necessarily used traditionally but are more resource prudent than conventional brick-mortar technologies have found a place in the compendium. A few notable technologies that can be applied to self-built housing sector are: Compressed Stabilized Earth Blocks (CSEB), stabilized mud blocks, rat-trap bond, filler slab, bamboo reinforced concrete, bio bricks from agriculture waste, etc.

Table 1: Compendium of indigenous innovative building materials and construction technologies

Compressed stabilized earth blocks (CSEB)	Ferrocement walling and roofing panels
 SOURCE: AUROVILLE EARTH INSTITUTE	 SOURCE: AUROVILLE EARTH INSTITUTE
Compressed stabilized earth blocks (CSEB) are made from local soil that has been mixed/stabilized with a small amount of cement (up to 5%), sand and water. To achieve the desired compressive strength, these blocks are compressed in a Press (manual or motorized) and cured for 28 days. The blocks can be solid, hollow, round, or customized depending on the application. These blocks can also be used to build columns, floors and roofs. Depending on the properties of the local soil, a design mix of local soil, cement, sand and water is prepared and cast in moulds via a press to produce blocks of the desired strength for the application. The technology allows soil from the site to be used, thus cutting down on transportation costs. The feasibility of the technology however depends on the local soil conditions.[1]	Ferrocement wall panels are thin reinforced concrete walls with closely spaced layers of continuous and relatively small wire mesh. The mesh could be made of metal or other suitable materials. Unlike traditional concrete, ferrocement can be formed into the desired shape without the use of a form. Because of its lighter weight, the building's dead load is reduced, allowing for a more cost-effective design. The parts can be cast locally near the construction site.[2]

Bamboo mat corrugated roofing sheet

SOURCE: BMTPC COMPENDIUM

Corrugated bamboo roofing sheets (CBRS) are made from woven bamboo mats which have been soaked in adhesive resin and then firmly pressed together. The mats are corrugated by pressing them between two corrugated pressing plates. The sheets can be produced in a variety of sizes to meet specific requirements and can be easily trimmed for special situations. Bamboo is the only raw material used in the production of sheets. The sheets are long-lasting and stable, and they are resistant to pests, severe weather and fire.[3]

Filler slab

SOURCE: SUGEET GROVER

In this technology, the concrete in tension zone is partially replaced with lightweight and low-cost filler material. The placement of the filler materials ensures that structural strength, stability and durability are not compromised, resulting in the replacement of non–functioning concrete. Low-grade Mangalore tiles, Thermopolis Burnt Clay Bricks, hollow concrete blocks, stabilized mud blocks/hollow mud blocks, inverted clay pots, coconut shells, AAC blocks, and other lightweight, inert and inexpensive materials can be used as filler materials. These materials are laid in the grids of steel reinforcement and concrete topping is done over them.

Funicular shells

SOURCE: ACADEMY FOR SUSTAINABLE HABITAT RESEARCH AND ACTION

A Funicular shell is a three-dimensional catenary supported by a rectilinear base. The roofing system is made up of doubly curved shells made of high compressive strength materials like waste stone pieces and brick tiles and supported by reinforced concrete edge beams. A series of these shells in varying geometric configurations supported on a grid of concrete beams, similar to a coffer slab, provides an appealing roof for small to medium spans.[4]

Ferrocement channels

SOURCE: AB LALL ARCHITECTS

Pre-cast ferrocement roofing channels have a segmental arch profile and span over two supports. Ferrocement consists of a uniform distribution of reinforcement via chicken wire mesh and welded mesh encapsulated in rich cement mortar, resulting in a significant reduction in both steel reinforcement and dead weight of the roof.[5]

Agrocrete bricks

IMAGE COURTESY: WWW.GREENJAMS.IN

Agrocrete bricks/blocks are made from crop residues such as paddy straw, cotton stalk, bagasse and so on, as well as industrial by-products such as slags, ashes and lime sludge. These solid load-bearing blocks are an alternative to burnt clay bricks and can support structures up to G+1 or be used in partition walls in multi-story building.[6]

Bio bricks from agricultural waste

IMAGE COURTESY: BMTPC COMPENDIUM

Bio bricks are a sustainable building material made from agricultural waste that can be used instead of burnt clay bricks. The product serves two functions: waste management and the development of environmentally friendly, sustainable buildings. The production of bio bricks begins with the careful selection of dry agricultural waste such as paddy straw, wheat straw, sugarcane bagasse and cotton plant. The agro-waste is chopped to the desired size and mixed by hand or mixer with a lime-based slurry and water. To make compact bricks, the mixture is poured into moulds and thoroughly compacted with a wooden dowel.[7]

Brick pyramidal roof

SOURCE: SUGEET GROVER

The pyramid-shaped roof is built on-site with locally sourced burnt clay bricks and cement mortar. No steel bars are used on the roof. Pyramidal brick roofs are shaped with an equal pitch on both sides and have good aerodynamic features, allowing them to withstand strong winds better than standard gable roofs. As a result, they are ideal for use in coastal areas where strong winds and storms are common. To reduce wind forces, the roof slope is kept at about 16 degrees.[8]

Rammed earth walls

SOURCE: SUGEET GROVER

Construction of rammed earth walls entails compacting optimum moisture content (OMC) subsoil with adequate proportions of sand, gravel, clay and stabilizer. Soil mix is poured into the formwork to a depth of 10 to 250 mm (4 to 10 inches) and compacted to about 50 per cent of its original volume. The soil is compacted in batches or courses, to gradually build the wall up to the formwork's top. Rammed earth's compressive strength is determined by factors such as soil type, particle size distribution, amount of compaction and moisture content.[9]

Bamboo strip walling

SOURCE: BMTPC COMPENDIUM

In this system, an infill between framing members is provided for privacy and in-plane bracing for the overall stability of the structure when subjected to horizontal forces. The non-load bearing wall infill is made of a grid or woven mesh of split bamboos tied together with MS binding wire to form a tight panel. Panels are attached to columns and beams. The panel's outside face is covered with chicken wire mesh. On both sides of the panel, a 1:5 mix of cement sand mortar is applied to a finished thickness of about 30 mm. This can be built on-site if properly treated and seasoned bamboo is available.[10]

Kath-kuni

SOURCE: WWW.SAHAPEDIA.ORG

Kath-kuni is an indigenous construction technique found in the hills of northern India, particularly in Himachal Pradesh. Kath-kuni construction uses locally available wood and stone as primary building materials. Typically, the construction involves laying courses with an outer layer of random rubble masonry and wood laid out alternately. Kath-kuni walls are distinguished by interlocked layers of wood and stone at the corners. The walls are properly bound together by strong wooden members, which aid in the structure's resistance to earthquakes. It is a low-cost technology for hilly areas where stone is abundant and local timber is inexpensive.[11]

Dhajji Diwari

SOURCE: SEISMIC DESIGN - DHAJJI DEWARI REPORT - ARUP

Dhajji Diwari is a type of traditional building found in the western Himalayas. It is simple to build with local materials such as timber and masonry infill. Dhajji Diwari is made of a heavily braced timber frame. The relatively small space between the framing is filled with a stone or brick masonry wall laid in mud mortar. They are typically built on shallow stone masonry foundations. The finished walls are plastered with mud mortar.[12]

Rat trap bond

SOURCE: SUGEET GROVER

Rat trap bond is a masonry system that uses high strength standard 230 x 115 x 75 mm bricks to create walls with a 75 mm hollow space in the centre. This is accomplished by laying bricks on the edges of masonry work. The technique uses approximately 25 per cent less material than conventional 9 inch thick brickwork.[13]

Bamboo reinforced concrete	Reinforced Brick Concrete (RBC) slabs
 SOURCE: THE GUARDIAN This technology replaces steel in RCC structures with bamboo reinforcement, providing a cheaper and more sustainable alternative to steel-reinforced concrete structures while providing a comparable level of disaster resilience and durability. Bamboo's high tensile strength is used in conjunction with concrete to provide structural stability. To improve bonding between bamboo and concrete, appropriate adhesives are used. Once the bamboo has been chemically treated to prevent infestation and rotting, the quality and durability of bamboo reinforced concrete structures are comparable to steel reinforced concrete structures. Technology is appropriate for single and double-story houses in all climates.[14]	 SOURCE: CRPF WORKS MAGAZINE Reinforced Brick Concrete (RBC) slabs are widely used, particularly in the country's northern regions where high-quality bricks are available. RBC construction has been found to be strong and durable, as well as enabling quick construction. This method of construction involves laying high-strength bricks directly over formwork, with reinforcements in between joints, and then filling the joints with concrete. The bricks are laid flat on the formwork, with at least 25 mm gaps for steel bars. To prevent corrosion, this spacing can be increased to 60 mm. The gaps are then filled with reinforcement bars. After which concrete is poured into them, providing a clear cover for the reinforcing bars.[15]

Reinventing dying wisdom

Official compendiums of building materials have begun to include traditional materials and techniques. The architect community, along with the house owners, has started to promote hybrid systems. It is necessary to leverage this for scale and speed of adoption. There is an urgent need to reduce carbon and environmental footprint of self-built structures in a climate challenged world.

Therefore, CSE has taken this initiative to create this compendium solely focused on traditional construction material, technologies and skills in different climatic zones. This initiative spreads across 11 states including Odisha, West Bengal, Gujarat, Maharashtra, Rajasthan, Karnataka, Andhra Pradesh, Telangana, Uttar Pradesh, Uttarakhand and Chhattisgarh. This specially includes a deep dive assessment of technologies available in Odisha and West Bengal—the states which are most vulnerable to extreme weather events.

The methodology for the compilation of this compendium includes review of Census 2011 data on materials used for roof and walling of self-constructed houses, overview of materials and construction technologies that are currently prevalent in the self-built housing segment of Pradhan Mantri Awaas Yojana, and several reports and scientific literature.

Literature review was followed up with subject experts. The experts were provided with a form containing a list of materials and technologies. Corresponding to each item, the expert had to write the skills required for the construction material or technology to be applied and how the skill is to be acquired. In addition, experts validated the findings of the literature review. Based on this, the spatial spread of traditional construction technologies was mapped for 11 states.

This investigation has also shown that about 13 demonstration centres exist in the country that have integrated various walling and roofing techniques using traditional and neo-sustainable construction materials (see *Map 1: Technology demonstration centres in India*).

This assessment has also been supported by field investigation. Close to 50 rural locations were covered. Field visits involved interviews and group discussions with homeowners, masons and builders, and local architects. This helped us in understanding the changes in material usage and the reasons for the shift. Multiple media for documentation were used that include photographs and videos. Resource mapping of locally available building materials was carried out for different regions.

This compendium has documented ecosystem-specific dominant traditional materials, construction methods, architectural designs, local skills, techniques for adaptation to climatic stress, and a range of applications to integrate traditional techniques with the brick-and-mortar structures for fusion.

Special effort has been made to document the hybrid structures that have been created by several architects in different ecosystems to demonstrate the potential of these fusion technologies.

Figure 1: Methodology for compilation of the compendium

2021

BMTPC brings out compendium catering to self-built housing appropriate technologies

CSE's research

Literature review and expert interactions	LITERATURE REVIEW • Material documentation and published research EXPERT INTERACTION • Validating information from literature review
Identification of construction technologies in 11 states	Gujarat, Maharashtra, Rajasthan, Karnataka, Andhra Pradesh, Telangana, Uttar Pradesh, Uttarakhand, Chhattisgarh, West Bengal and Odisha
Location mapping and site visits to Odisha and West Bengal	

Map 1: Technology demonstration centres in India

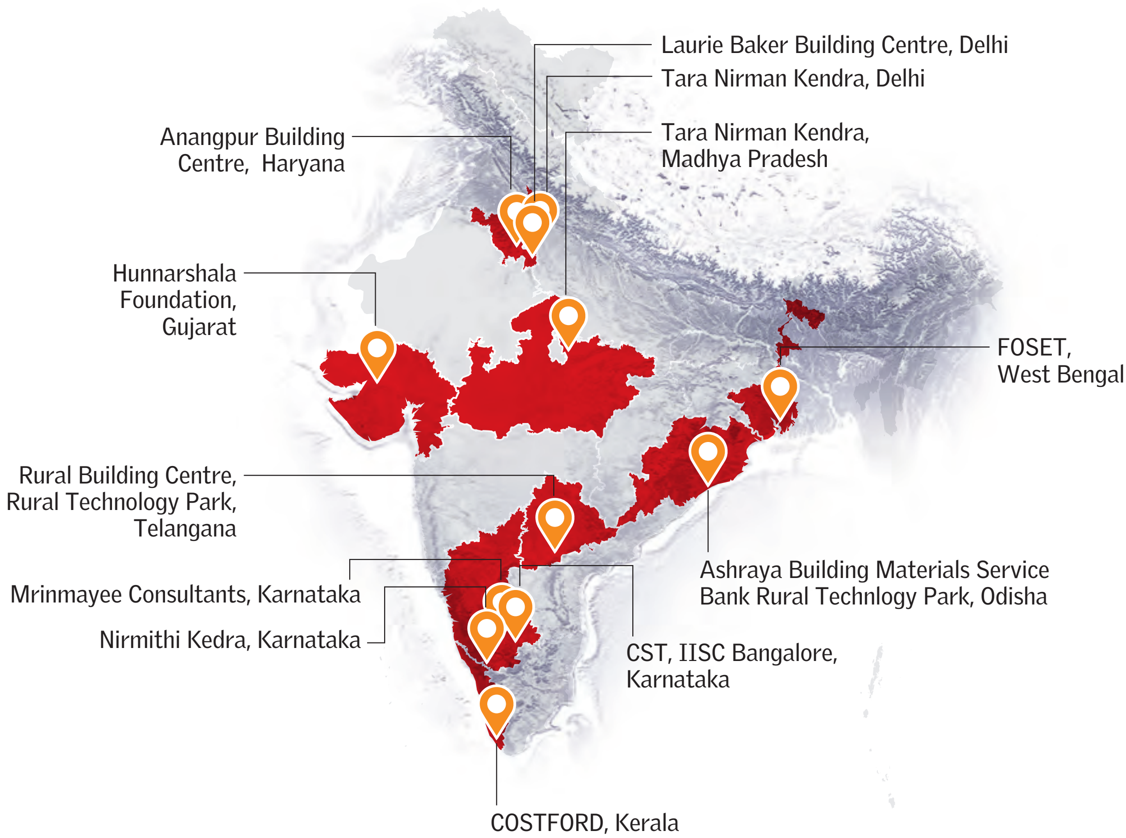
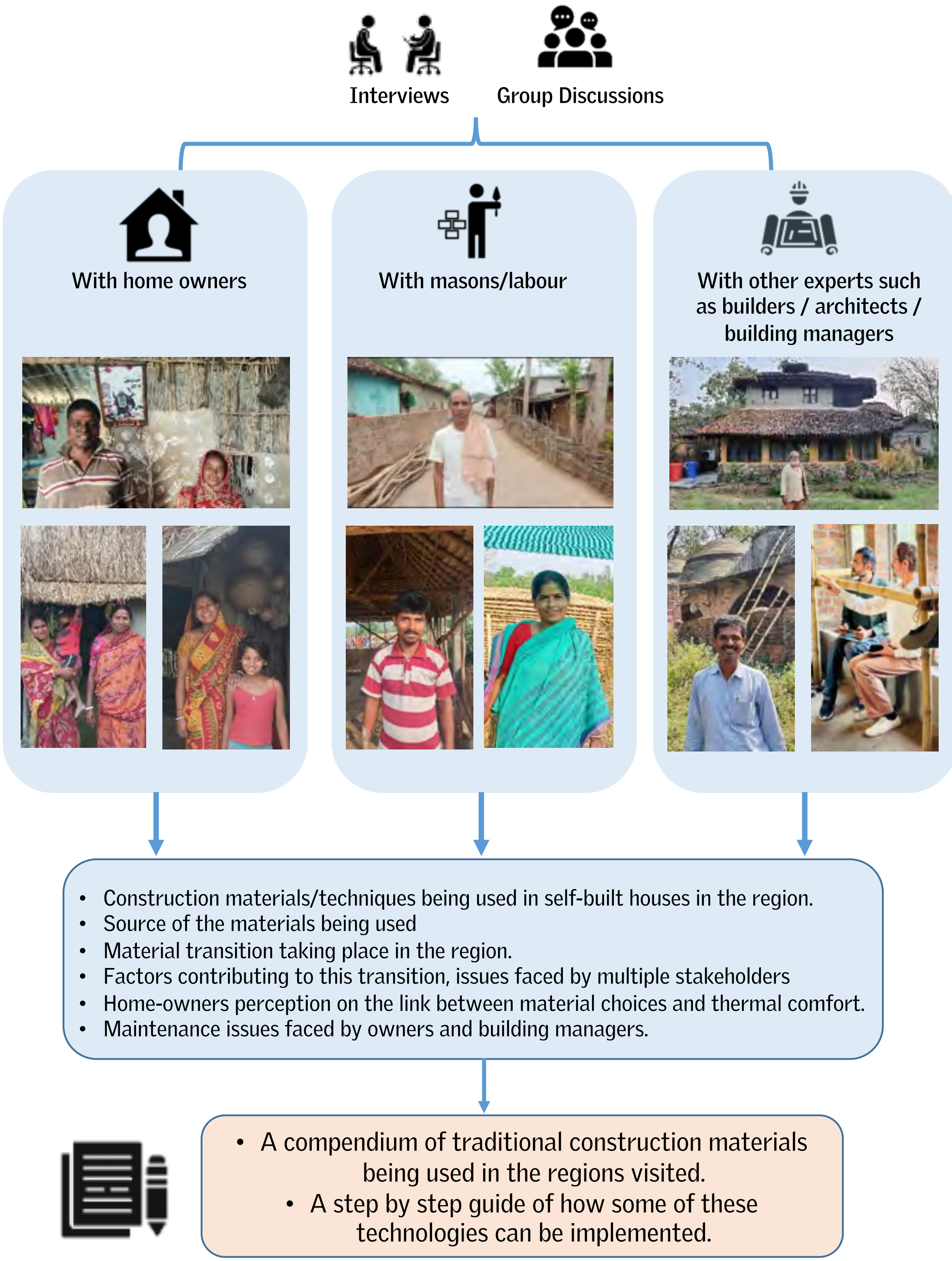


Table 2: Construction technologies taught in demonstration centres

Demonstration centre			Hunnar-shala Foun-dation	RTP, Hydera-bad	COST-FORD	Mrinmayee Consultants	Nirmithi Kendra	Tara Nirman Kendra	Lauri Baker Building Centre	Foset	CST, IISC Bangalore	Anangpur Building Centre	Ashraya Building Materials Service Bank	RTP, Bhuba-neswar
Region			Gujarat	AP/ Telangana	Kerala	Karnataka	Karnataka	New Delhi	New Delhi	West Bengal	Karnataka	Haryana	Odisha	Odisha
Climate			Hot-dry	Warm-humid	Warm-humid	Warm-humid	Warm-humid	Composite	Composite	Warm-humid	Warm-humid	Composite	Warm-humid	Warm-humid
Sr. no.	**Building typology**	**Construction techniques**	**ROOFING SYSTEMS**											
1	Roof	Space Frame	■									■		
2	Roof	Thatched Roof	■											
3	Roof	Filler Slab	■	■	■	■	■		■	■				
4	Roof	Sandwich Roof	■								■			
5	Roof	Bhunga Roof	■											
6	Roof	Shallow Dome	■											
7	Roof	Earthen Tiles Roof with Wooden Understructure	■											
8	Roof	Mangalore Tiled Roof		■	■		■							
9	Roof	Arched Roof		■		■								
10	Roof	Micro Concrete Roofing Tile		■			■	■					■	
11	Roof	Ferrocement Channel Roof		■			■	■					■	
12	Roof	Masonry Dome Roof		■	■	■	■		■		■	■		
13	Roof	Bamboo Corrugated Roofing Sheet		■										
14	Roof	Pre cast RCC panels over pre cast joists		■										■
15	Roof	Bamboo Roof			■								■	
16	Roof	Vaulted Roof				■	■				■			
17	Roof	Jack Arch Roof					■				■			
18	Roof	Brick Panel Roof using RCC joists					■							■
19	Roof	Funicular Shells										■		
20	Roof	Quilted Roofing										■		
21	Roof	Plank & Joist Roofing											■	
22	Roof	Corbelled Brick Pyramid Roof												■
Sr. no.	**Building typology**	**Construction techniques**	**Walling Systems**											
1	Wall	Stablised Rammed Earth	■	■		■					■			
2	Wall	Wattle & Daub	■	■										

Demonstration centre			Hunnar-shala Foun-dation	RTP, Hydera-bad	COST-FORD	Mrinmayee Consultants	Nirmithi Kendra	Tara Nirman Kendra	Lauri Baker Building Centre	Foset	CST, IISC Bangalore	Anangpur Building Centre	Ashraya Building Materials Service Bank	RTP, Bhuba-neswar
Region			Gujarat	AP/ Telangana	Kerala	Karnataka	Karnataka	New Delhi	New Delhi	West Bengal	Karnataka	Haryana	Odisha	Odisha
Climate			Hot-dry	Warm-humid	Warm-humid	Warm-humid	Warm-humid	Composite	Composite	Warm-humid	Warm-humid	Composite	Warm-humid	Warm-humid
3	Wall	Adobe Wall	■	■		■						■		
4	Wall	RR Stone Masonry	■	■							■			
5	Wall	CSEB	■			■		■			■		■	
6	Wall	Rat Trap Bond	■	■	■		■		■	■			■	■
7	Wall	Bhunga Wall	■											
8	Wall	Flyash Bricks		■							■		■	
9	Wall	Tile Facing Adobe Mud Blocks		■										
10	Wall	Cement Slablised Mud Blocks		■			■							
11	Wall	Coursed Rubble Masonry		■										
12	Wall	Hollow Concrete Blocks		■			■						■	
13	Wall	Jali Wall			■									
14	Wall	Half Brick Wall, Exposed Brick Wall			■									
15	Wall	Solid Concrete Blocks					■	■					■	
16	Wall	Boulder blocks or rubble filler blocks					■							■
17	Wall	Mud Plastered Brick Wall							■					
18	Wall	Arched Wall							■					
19	Wall	Brick Arches								■				
20	Wall	Fly Ash-Lime-Gypsum Bricks									■			
21	Wall	Precast Ferrocement Panels									■			
22	Wall	Containment Reinforcement Walling System									■			
23	Wall	Geopolymer & alkali activated bricks									■			
24	Wall	Hollow Core Interlocking Blocks										■		
25	Wall	Pretensioned Wall										■		

Figure 2: Stakeholders interviewed during field visits



Next steps

Even though official documentation of traditional building materials and techniques has begun, more focussed policy framing is needed to promote, support and fund hybrid and fusion technologies in the self-built housing sector, especially in peri-urban and rural areas. This will require deliberate strategies.

Develop a comprehensive compendium and knowledge repository of traditional and fusion construction technologies to inform self-built housing programmes: Through its compendium of indigenous technologies, BMTPC has started recognizing traditional technologies. This needs to be taken forward for more comprehensive documentation. State governments also need to document more technologies for the self-built housing segment while taking into account the local nuances based on material availability. There is immense diversity in traditional materials and building techniques nation-wide that needs mapping as well as support from the technology demonstration centres and research conducted by institutions.

Provide guidelines, norms, and certify traditional and fusion technologies: The biggest roadblock for mainstreaming of traditional and fusion technologies is the lack of testing and certification of these technologies. While scientific literature has proven the thermal comfort and disaster resilience benefits of most of these technologies, absence of standards and tested evidences has prevented their uptake in the market. These technologies need to be evaluated for their performance on thermal comfort and disaster resilience. Based on this technical evaluation, traditional and fusion technologies and the skills related to them need to be certified. Some initiatives like those pioneered by organizations like Hunnarshala in Gujarat have already begun to generate more data and evidence on these technologies. This needs to be taken forward at scale.

Mobilize informal knowledge and skills to strengthen the sector: Knowledge and skill of traditional technologies is largely transferred informally. It is either passed on from one generation to another or through informal instruction by a mason. This network of masons has great potential for demonstration-based learning and skilling. A step-by-step guidebook needs to be created to capture the skill. This must be linked with the knowledge repository. For dissemination and further skilling, state governments need to create local institutional frameworks that facilitate networking between trainees and trainers and roll out under skilling and livelihood programmes. Certification of traditional technologies and skills can catalyse significant changes.

Develop prototypes at innovation and demonstration centres: There are many technology demonstration centres in India. This investigation captured 12 such centres. There is potential to demonstrate more traditional and fusion technologies at these centres. All state governments must develop prototypes based on the documented technologies for demonstration-based learning. Funding strategy and policies need to support hybrid approaches and local technologies to promote their use in contemporary modern self-built houses in both rural and urban areas. Several projects or architects and practitioners have already demonstrated how the combination of traditional and new technologies can work efficiently while improving thermal comfort, durability and cost effectiveness. Innovative use of conventional materials like burnt-clay bricks, cement, concrete, etc. along with the new material can provide a range of solutions for sustainability. These need to be demonstrated and promoted.

Need zoning for climate-appropriate response in promotion of construction technologies: Different parts of any state face varied exposure to disasters and climate vulnerability. For instance, Odisha has a coastline that is frequented by high-speed winds and cyclones while it also has hilly forest areas with different kinds of vulnerability. Similarly, West Bengal has a highly eco-sensitive Sundarbans region as well as the hill districts of Darjeeling and Kalimpong. To address this variability, states need to zone their areas and guide choices of construction technology and materials accordingly. Vulnerability mapping will be crucial in order to provide an appropriate response.

Update schedule of rates for formal adoption of these materials: The states need to include traditional and hybrid technologies and the materials used under them in their schedule of rates for procurement. This will push uptake and mainstream these technologies in the construction sector.

Chapter 2: Traditional construction technologies

The Indian subcontinent has always had a rich knowledge base of construction technologies. The rural geographies of this region have been shaped significantly by local know-how on availability of materials and different techniques for their use. Dwellings are largely constructed by the occupants or by the informal sector, and can withstand harsh temperatures and even extreme weather events like cyclones or earthquakes. Even though the self-built housing segment dominates India's housing landscape, this traditional knowledge on construction technologies is neither adequately documented nor promoted.

In its investigation on traditional construction technologies and their potential for green recovery, CSE has compiled some of the predominant technologies in India. This chapter comprises of these technologies spread across 11 states—Odisha, West Bengal, Gujarat, Maharashtra, Rajasthan, Karnataka, Andhra Pradesh, Telangana, Uttar Pradesh, Uttarakhand and Chhattisgarh. This also includes a deep dive assessment of technologies available in Odisha and West Bengal—the states that were hit the most by reverse migration due to the COVID-19 lockdown.

The following section comprises 45 traditional walling and roofing technologies that were identified through literature review and expert consultation.

Traditional roofing technologies

Curved country tiled roof: These tiles are made of locally available soil and usually prepared by the potters of the village. These tiles mount on either a wood or bamboo frame. They are semi-cylindrical in shape; the bottom layer of the tile is placed in such a way that the trough of the tile faces upwards, and an inverted curved tile is placed to cover the gap between the two bottom tiles, with its edges resting on the troughs of the bottom tiles.

SOURCE: SUGEET GROVER

Flat clay tiles: These are flat earthen clay tiles which are locally made. After preparing the soil mixture, they are hand-moulded or made from casts and burnt in a kiln. They are made with a small projection on the bottom of the tile, that locks with the top surface of the overlapping tile and interlock with each other.

SOURCE: HARIKRISHNAN C U

Mangalore roofing tiles: These tiles are native to the southern region of Karnataka, in and around the town of Mangalore. They are factory-made flat tiles with interlocking mechanism. They are laid at steep angles, generally at 45 degrees.

SOURCE: THE HINDU, BUSINESS LINE

Slate roof: Slate is one of the most long-lasting roofing materials, sometimes lasting more than 100 years. Natural stone is mined and cut to make a type of shingle, a thin, tapered piece of material used as a roof and wall covering. Slates can either be nailed at the centre line or near the top.[16]

SOURCE: NUPUR PANDEY

Stone roof*:* Stone roofs may be flat or pitched. Large slabs are usually used for flat roofs and small ones for pitched roofs. Traditionally, the stone slabs are placed on wooden beams. In contemporary methods, stone slabs rest over steel or slender reinforced cement concrete section beams. The slabs are laid such that they provide a slope for rainwater drainage.[17]

SOURCE: THANNAL NATURAL HOMES

Jack arched roof construction: Jack arch roof is composed of arches of either brick or concrete blocks, supported on rolled steel joists (RSJs), steel girders, or any other horizontally spanning member. It reduces the amount of steel and concrete compared to conventional reinforced cement concrete slabs.[18]

SOURCE: THE HINDU

Brick arch roof: A long arch profile is used as a base for the panel. Bricks like WPC (Water Proof Course) and cladding bricks with good compressive strength and adherence quality are placed flat-faced along the curve to achieve the arch-shaped panels. There are four types of brick arched roofs: rough brick arches, axed brick arches, gauged brick arches and purpose-made brick arches.[19]

SOURCE: AUROVILLE EARTH INSTITUTE

Traditional Ikra roof construction: Ikra is a type of reed that grows wildly in river plains and near lakes across the states of Bihar, UP, Odisha, Assam, West Bengal and Sikkim. Traditional Ikra roof generally consists of Ikra reeds, attached to wood/bamboo trusses, which laterally connects to the parallel walls. Nowadays, construction of such houses is on the decline due to various reasons such as the lack of availability of reed, increased maintenance and vulnerability to fire.[20]

SOURCE: BVMENGINEERING.AC.IN

Thatch roof: Straw of grass is made into bundles and placed on top of timber/ bamboo rafters. Agricultural by-products are also used for the same. This acts as an insulator and helps in keeping the inside of the building warm during winters and cold during summers. The pitch of the roof is found to vary in different areas depending on the wind velocity experienced in the region. They are susceptible to fires and must be maintained on a periodic basis as they are subject to wear and tear by rain and wind.

SOURCE: SUGEET GROVER

Leaf thatched roof: Wild leaves such as that of Sal are also used as thatch for constructing thatched roofs. They are sometimes used in dual or triple layers for creating thicker thatching. They have to be maintained on a periodic basis as they undergo wear and tear from rain and wind.

SOURCE: HARIKRISHNAN C U

Bhunga roof*:* This type of conical thatch roof is prevalent on all the Bhunga houses in the villages in Banni, Pachham, and other desert areas of Rajasthan. This roof consists of a thick layer of grass that rests on a cir frame forming a cone. Straw bundles which are locally known as *Kheep* are tied to the roof structure. The grass thatch has to be replaced annually. It is a lightweight roof.[21]

SOURCE: RETHINKING THE FUTURE

Chutillu house thatched roof: Chutillu houses are circular in form for stability. They are thatched with rafters which come from palmyra palm. Chutillu thatches usually overhang leaning towards the ground to protect the soil-based walls from rains and extreme heat. The roof slope is kept at a minimum of 45 degrees. They are found in the states of Andhra Pradesh and Telangana.[22]

SOURCE: HTTPS://WWW.DAKSHINACHITRA.NET/COASTAL_ANDHRA_HOUSE

Madras terrace roof: This roofing involves the use of wood, "aachikal" (a locally available material which is a small brick), and lime plaster. These are used for relatively small spans. Wooden beams are spaced no more than 45 cm apart from one another. Bricks are laid upon this layer on the edges across, in a diagonal pattern, plastered with lime. [23]

SOURCE: WWW.THEMUDHOME.COM

Shallow dome: These domes are a combination of ring beam and brick vaults. These are built with bricks with lime mortar and the rise of the dome varies from roughly 9 inches to 2 feet. There are mainly two types of shallow domes masonry, which are built in western U.P. and Haryana, namely dish type and the tray type. These are built in two methods—one with shuttering and one without shuttering.[24]

SOURCE: HTTPS://KAKANIASSOCIATES.WIXSITE.COM

Pathal roof system: In this type of stone roofing found in Uttarakhand, the top layer of material has traditionally been *Pathal* or stone, either in the form of large, irregular, and heavy slabs or thinner and lighter stone slates which are mostly irregular in shape. The elements that support these stones include properly cut planks, rough-hewn planks, small diameter branches, and *ringaal* (cane like grass that grows in the hills) depending upon availability and affordability.[25]

SOURCE: NUPUR PANDEY

Bagra flat lime roof: Crushed lime waste or 'Bagra' is widely used in mortars, plasters and flat lime roofs in the village of Tehla, near Jaipur. Soaked fenugreek seeds, guggal (*commiphora mukul*), jaggery and other ingredients are added to this to impart desirable qualities of strength and decreased setting time in lime. As spanning members, wooden logs serve as the roof's foundation. The following layer is made up of large stone slabs laid with bagra mortar to fill in the gaps between the wooden members. Above this, smaller stones with more bagra are laid to fill the gaps between the joints and make them impermeable. The final finish is a nearly 2" thick layer of bagra which is leak-proof.[26]

SOURCE: THANNAL NATURAL HOMES

Patod stone house roof: In this technique, the pink sandstone (Jodhpuri patti) is used for roofing. The stone slabs are laid on top of the rafters, overlapping each other. Because these roofs are monolith stone slabs, they do not require a steep 45-degree slope, which saves on materials. These roofing slabs may have a few small gaps between them. The joints between the two slabs are sealed with lime 'bagra' to prevent leaks. These slabs are sometimes covered with kuncha reed thatch (*Saccharum munja*).[27]

Stone patti with mud phuska: This technique uses locally available earth, straw, cow dung and sand-bitumen to construct a waterproof roofing system. Stone pattis are used as an insulating medium for the roof. A layer of hot bitumen is spread over it and a layer of coarse sand is immediately spread over the hot coat of bitumen. Mud phuska is prepared from puddle clay mixed with *bhusa* (straw) and a 10 cm thick layer of this is applied over the sand-bitumen layer and made in a slope (usually 1:40). It is then plastered with roughly 13–15 mm coat of mud-cow dung mortar (3:1).[28]

Traditional walling technologies

Wattle and daub wall: It has a lattice of interwoven rods made of twigs, local wood and bamboo splits called wattle which is then plastered with a mixture 'daub' which is made of wet clayey soil, cow dung and often straw. The soil used for the technology is generally more clayey when compared to the soil mixture used in cob walls. These walls are relatively thinner than their cob wall counterparts, usually coming up to a size of roughly 15–20 cm. During flooding, the daub gets soaked and damaged, while the wattle remains relatively intact, which is then plastered again as part of periodic maintenance.

SOURCE: SUGEET GROVER

Sun dried bricks wall: Bricks are cut in a parallelogram shape from the clayey agricultural soil and put out to dry, then placed in courses. This technique is rarely used and was only found in a few houses in Purb Sridharpur during the study.

SOURCE: SUGEET GROVER

Cob-based wall: This type of wall is structured using a mixture of soil (sand and clay), straw and, in some cases, lime. The clay component in the mortar imparts the binding property, the sandy part gives it strength, while the straw makes it less brittle by giving tensile strength. The straw also provides the wall with insulating properties. The proportions and composition of the mixture hence depend upon the type of soil used. The wet soil mixture is placed in horizontal courses and left to dry off before placing the next course on top of it.

SOURCE: SUGEET GROVER

Laterite blocks wall: Laterite blocks are available in many coastal regions such as parts of Odisha, Meghalaya, Andhra Pradesh, Bihar, Maharashtra, Karnataka, Goa, Tamil Nadu and Kerala. These blocks are cut and used for making walls with the help of mud and lime mortar or cement mortar. Laterite is used traditionally in building walls, columns and plinths, and is cut and shaped to the required sizes for each element. Nowadays, cement acts as a binding material rather than mud.

SOURCE: SUGEET GROVER

Random rubble masonry wall: Irregular-sized and shaped stones are used to create this type of wall. They are basically stacked and layered on top of one another and both mud and cement/lime mortar act as binding materials. This type of technology is relatively very durable and some of the houses that were observed in the study had lasted for several decades.

SOURCE: SUGEET GROVER

Bhunga wall: The walls of a Bhunga house, predominantly found in Gujarat, are made in cob-based, as well as wattle- and daub-based methods. They are made from locally available materials like soil, bamboo, timber, etc. A structure is constructed by tying bamboo sticks with grass ropes. After that, cow dung and mud are used as the wall plaster to make them stronger. This kind of wall requires periodic maintenance as mud cracks in the extreme heat[29]

SOURCE: HTTPS://THEDIPLOMAT.COM/2018/08/THE-EARTHQUAKE-PROOF-HUTS-OF-KUTCH/

Adobe block wall: Adobe blocks use organic materials such as clayey soil and straw. They are traditionally made in open cast moulds and left to sun-dry. They are laid using an earth mortar and smoothened with mud plaster as the wall

SOURCE: SUGEET GROVER

finishes. These bricks are fire-resistant, flexible, durable, and provide sufficient thermal mass to ensure good energy efficiency and sound insulation.

Rammed earth wall: Rammed earth consists of compacting successive layers of soil inside a formwork to obtain a homogeneous wall formed with compacted earth. 'Unstabilized" rammed earth means that there are no additional binder elements (such as cement or lime). The soil is mixed with natural materials such as earth, chalk, lime, and/or gravel in adequate proportions. Lime or cement is added as a stabilizer and the soil is filled into the formwork and compacted in courses, up to the formwork's top. The strength of the wall is determined by multiple factors such as particle size distribution, compaction and type of soil.[30]

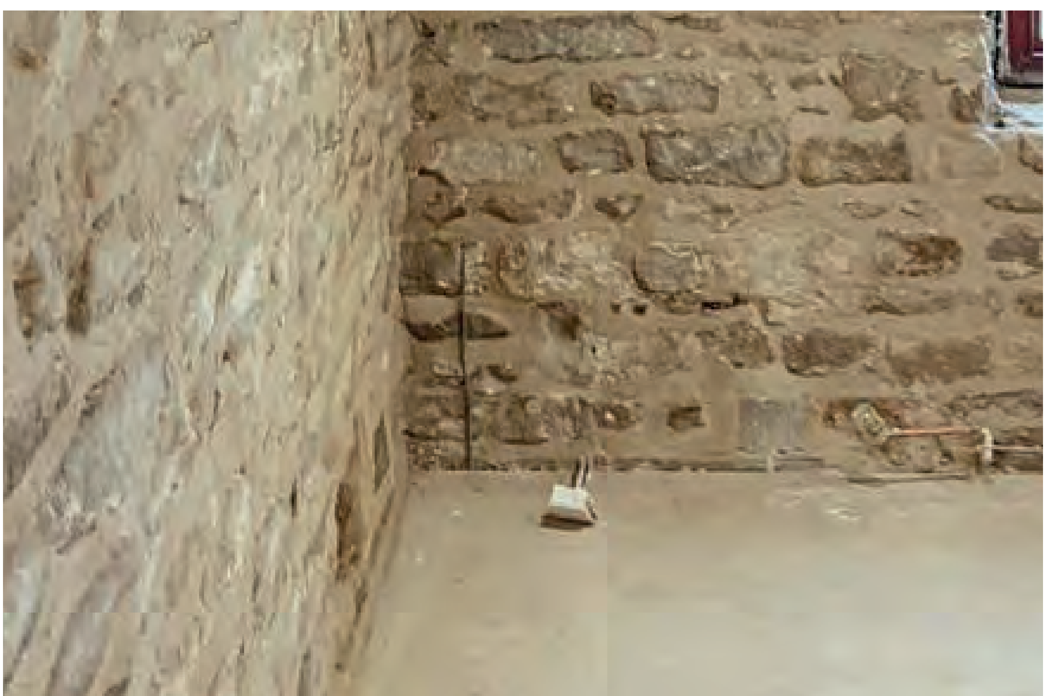
SOURCE: AUROVILLE EARTH INSTITUTE

Dhariya Munia (dressed stone masonry) wall*:* Dressed stone masonry or *Dharia Munia* substantially uses mud mortar or urad (pulse) mortar for binding the stones. Each stone is roughly 300 to 900 mm long and 220 mm wide with a thickness of roughly 150 mm. The walls are roughly 450 mm thick. [31]

Koti Banal wall: In *Koti Banal* houses, the walls consist of a wooden cribbage configuration with orthogonally arranged wooden logs interconnected at the junctions by wooden pins/tenons (*Gujja Khoonta*). Single wooden logs are used for the two bottom-most layers, while double wooden logs are used for the upper layers. The open space between the wooden logs fills with well-dressed flat stones which are dry-packed or by using a paste of pulses or mortar. [32]

SOURCE: 5 VERNACULAR ARCHITECTURE STYLES IN INDIA - RTF | RETHINKING THE FUTURE

Coursed natural stone masonry wall: This kind of technology uses natural stones which are cut and shaped into rectangular blocks. These blocks are then laid in coursework and bound together using lime, mud or cement mortar.



SOURCE: WWW.ROSIEANDTHEFARM.CO.UK

Patod stone house wall: This type of walling technology is found predominantly in the rural regions of Rajasthan. Slabs of pink sandstone, locally known as Jodhpuri patti, are used for making the structural framework of these houses. Such homes made of these stones are known as Patod. The basic framework remains the same but the infill—such as stones, mud, bricks, kuncha reed, etc.—that is used to cover these vary according to their availability. [33]

Araish plaster and Surkhi*:* Araish (polished lime) plastering technology is native to Rajasthan. It is made from quick lime and marble powder, and is waterproof and durable. It usually forms by combining finely sieved slaked lime with marble powder. After that, it is ground to a fine paste and then applied over Thappi or Lohi plaster.

Surkhi is the layer over the stone walls. It is the base coat that uses slaked lime, brick powder, Gogol (incense), natural gum, fenugreek seeds, water, jaggery, and kesula or Palash flowers. All ingredients are mixed and kept for fermentation for final use. [34]

Zikki plaster and Surkhi*:* This walling technology uses zikki plaster, the mixture of an equal quantity of slaked lime and marble dust. This layer acts as the next base layer for the Araish finish. It gives a glossy finish to walls and provides thermal comfort.[35]

Kodi marble plaster: Kodi marble plastering is an indigenous technique used in Rajasthan in traditional houses. This plaster is made of lime mixed with mortar and marble powder. It also uses additional organic colours (Haldi, Neel, etc.) to give a vibrant look to walls and their finish.[36]

Lime-based plaster: Two parts of river sand add to one portion of the powdered lime waste to form lime based plaster. Also, with this mix, overnight soaked methi water with jaggery water is used to enhance the strength and its workability.[37]

SOURCE: HUNNARSHALA FOUNDATION

Wooden panels/Bamboo with mud mortar walls*:* This walling technology uses bamboo poles/bamboo when it is readily and efficiently available in the region. A skeleton structure is made using bamboo poles (which may or may not split) stuck close to each other and plastered with earth.

Khondolite block walls: Khondolite blocks walling technology was predominantly used in the construction of ancient temples. These blocks are cut and put in layers as different courses and bound with mud/lime/cement mortar.

Traditional intermediate floor technologies

Kadi baraga floor: Kadi means the timber beams and baraga means the timber/bamboo runner. This is typically a form of a flat roof or intermediate floor made with wood/bamboo.

Sor grass floor: Bundles of locally available Sor grass are used for making intermediate floors; these are then layered with mud and thatch for the final finish.

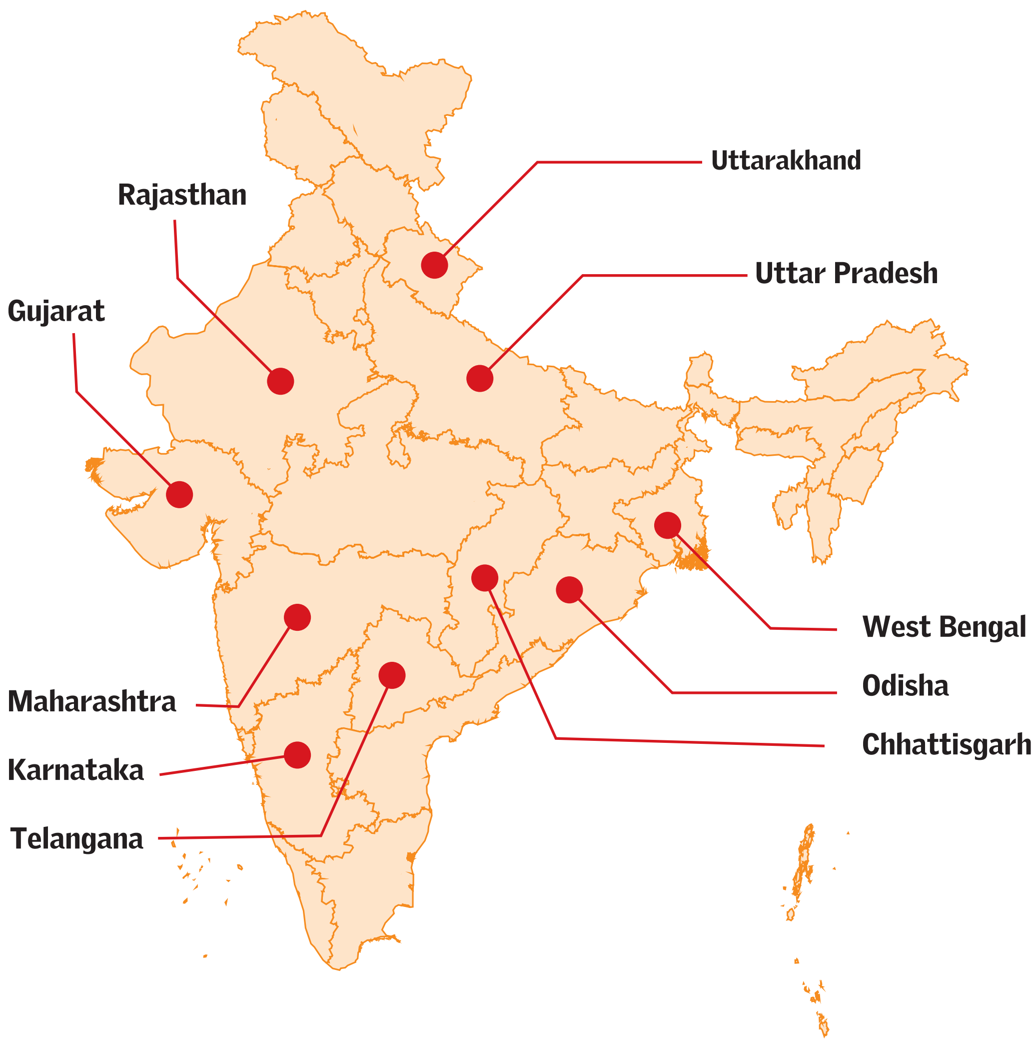
Bamboo/wooden floor: Tal (date palm) wood is used as the runner that spans the room and bamboo or wooden members are used above this. The mud and thatch mixture acts as the final finishing layer. Wooden floors are easy to clean and less likely to be damaged.

Traditional foundation technologies

Koti banal foundation (dry stone masonry)*:* Koti banal structures rest upon a raised dry stone masonry platform over a foundation of rubble masonry in the lower part. The multi-storeyed traditional structures are constructed on a raised solid stone platform that is the continuation of the filled-in foundation trench above the ground. The height of the platform varies between roughly 6 and 12 feet above the ground. A massive solid platform at the base of the structure helps keep the centre of gravity and centre of mass close to the ground. This minimizes the overturning effect of the tall structure during seismic loading.[38]

These traditional technologies were found to be present in 11 states (see *Map 2: States investigated for traditional walling and roofing technologies*) but are not limited to these states.

Map 2: States investigated for traditional walling and roofing technologies



Deep dive: Odisha and West Bengal

CSE conducted a deep-dive investigation of traditional technologies in Odisha and West Bengal. Overall, 13 locations—six in West Bengal and seven in Odisha—were visited. Several traditional walling and roofing materials and techniques were observed in these locations. Around six types of traditional walling technologies were found in Odisha along with three types of roofs and one technology for intermediate floors. In the state of West Bengal, three types of roofs and four types of traditional walls were found.

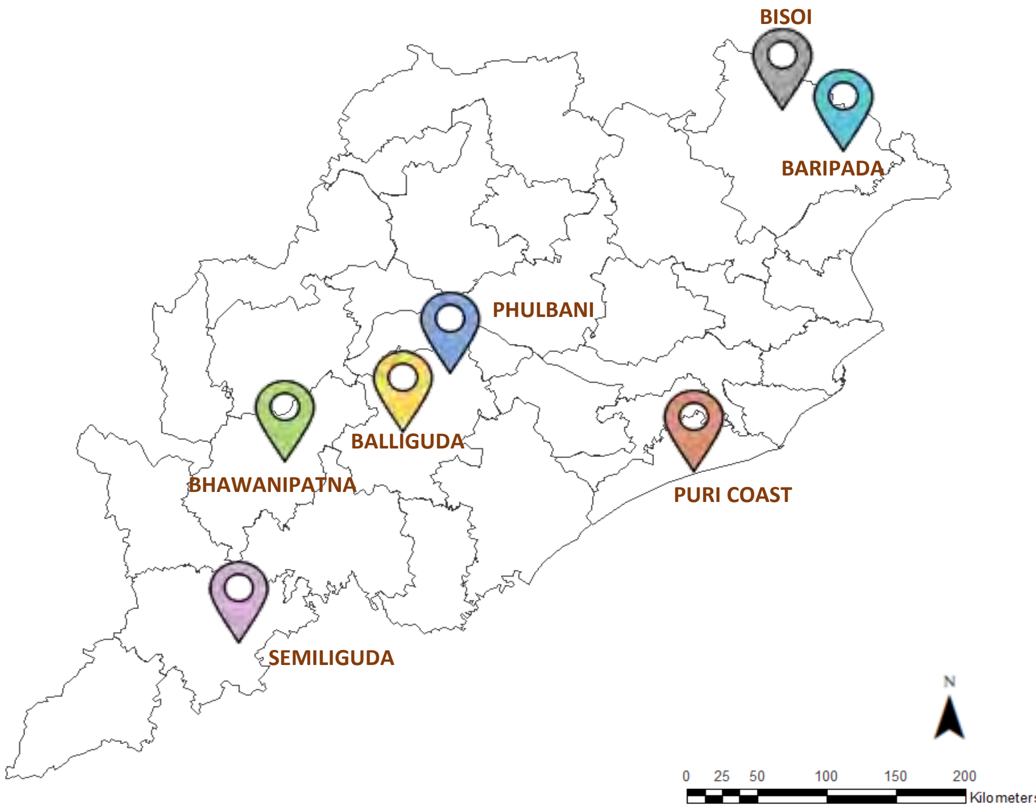
Table 2: Construction materials and techniques documented in Odisha

Walling materials/techniques	• Wattle and Daub • Cob wall • Laterite block • Stone-Slats masonry • Random Rubble masonry • Wooden plank wall – mud plaster
Roofing materials/techniques	• Curved country tiles with timber/bamboo under structure • Thatch roof • Terracotta flat tiles with timber under structure
Intermediate floor	• Kadi Baraga intermediate floor

Table 3: Construction materials and techniques documented in West Bengal

Walling materials/techniques	• Wattle and Daub • Cob wall • Random Rubble masonry • Sun dried bricks
Roofing materials/techniques	• Thatch roof • Terracotta flat tiles with timber under structure • Curved country tiles
Intermediate floor	• Kadi Baraga intermediate floor • Sor grass flooring

Map 3: Traditional construction technologies and their locations in Odisha

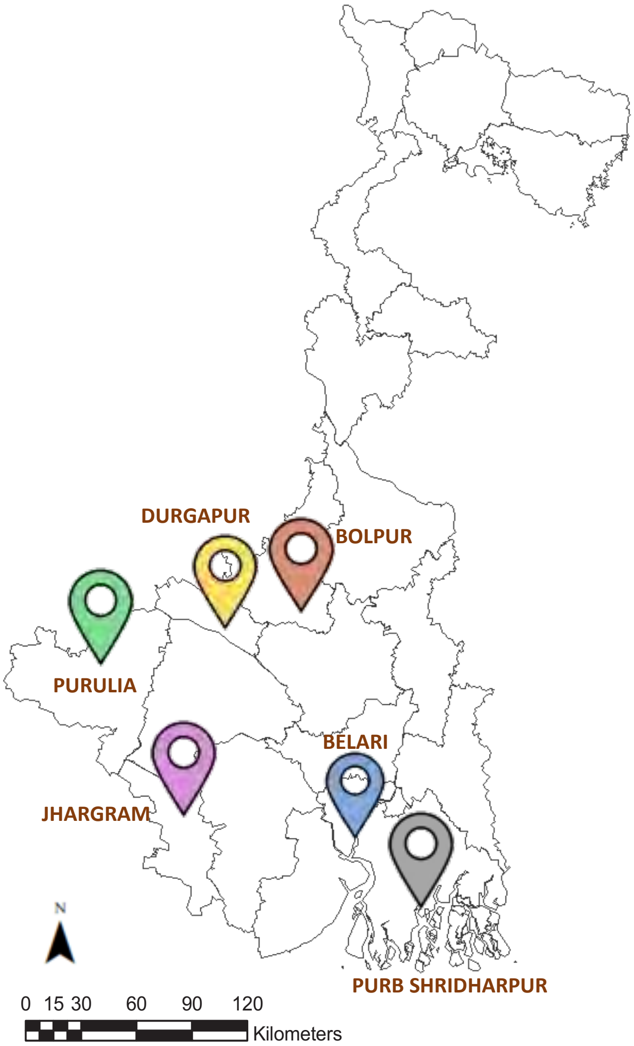


Walling materials/techniques found in region	
W1	Wattle and Daub
W2	Cob wall
W3	Laterite block
W4	Flat stone masonry
W5	Random rubble
W6	Wooden panel with mud plaster
Roofing materials/techniques found in region	
R1	Curved country tiles
R2	Straw thatched roof
R3	Leaf thatched roof
R4	Terracotta flat tiles
Intermediate floors found in region	
F1	Kadi Baraga floor (Bamboo/wood)

Sr. no.	Location	District	Material/ technique	Colour code
1	Baripada	Mayurbhanj	W1, W4, W2, R1, R2, R4	
2	Bisoi	Mayurbhanj	W1, W2, R1, R2, R3, R4	
3	Bhawanipatna	Kalahandi	W1, W2, R1, F1	
4	Semiliguda	Koraput	W2, W5, R2, R4	
5	Puri coast	Puri	W1, W2, W3, R2, R4	
6	Balliguda	Kandhamal	W2, W6, R1, R2, R4	
7	Phulbani	Kandhamal	W2, W6, R1,R2, R3, R4	

Source: CSE

Map 4: Traditional construction technologies and their locations in West Bengal



Walling materials/techniques fo in region	
W1	Wattle and Daub
W2	Cob wall
W3	Random rubble
W4	Sun dried bricks
Roofing materials/techniques fo in region	
R1	Straw thatched roof
R2	Terracotta flat tiles
R3	Curved country tiles
R5	Filler slab
Intermediate flooring found in region	
F1	Kadi Baraga floor (Bamboo/wood)
F2	Sor grass floor

Sr. no.	Location	District	Material/technique	Colou code
1	Durgapur	Paschim Bardhaman	W2, R1, , R2	
2	Jhargram	Jhargram	W1, W2, R1, R2, F1	
3	Bolpur	Bhirbhum	W2, R1, F1, F2	
4	Belari	Howrah	W1, R2	
5	Purulia	Purulia	W2, W3, R1, R2, R3	
6	Purb Shridharpur	S. Parganas	W1, W4, R1, R2, F1	

Source: CSE

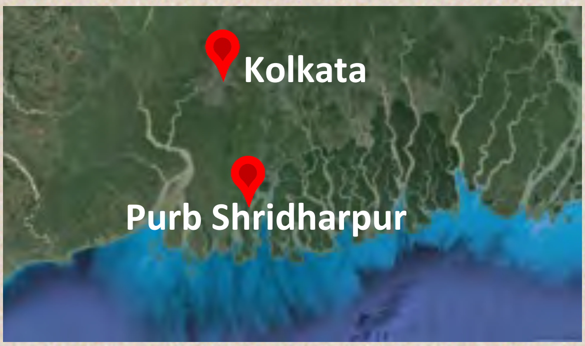
Chapter 3

Case studies

DOCUMENTATION AND RESOURCE MAPPING OF TRADITIONAL TECHNOLOGIES IN WEST BENGAL

01

PURB SHRIDHARPUR



Location: 90 km from Kolkata
Geomorphological classification: Flood plain
Climate: Warm and humid

Context | Geography | Vegetation

Purb Shridharpur is a village located in the Sundarbans delta region. Rising and sinking sea levels is an intrinsic part of everyday life in this area. Fishing, fish farming and agriculture are the main occupations of the residing community.

Inland water bodies

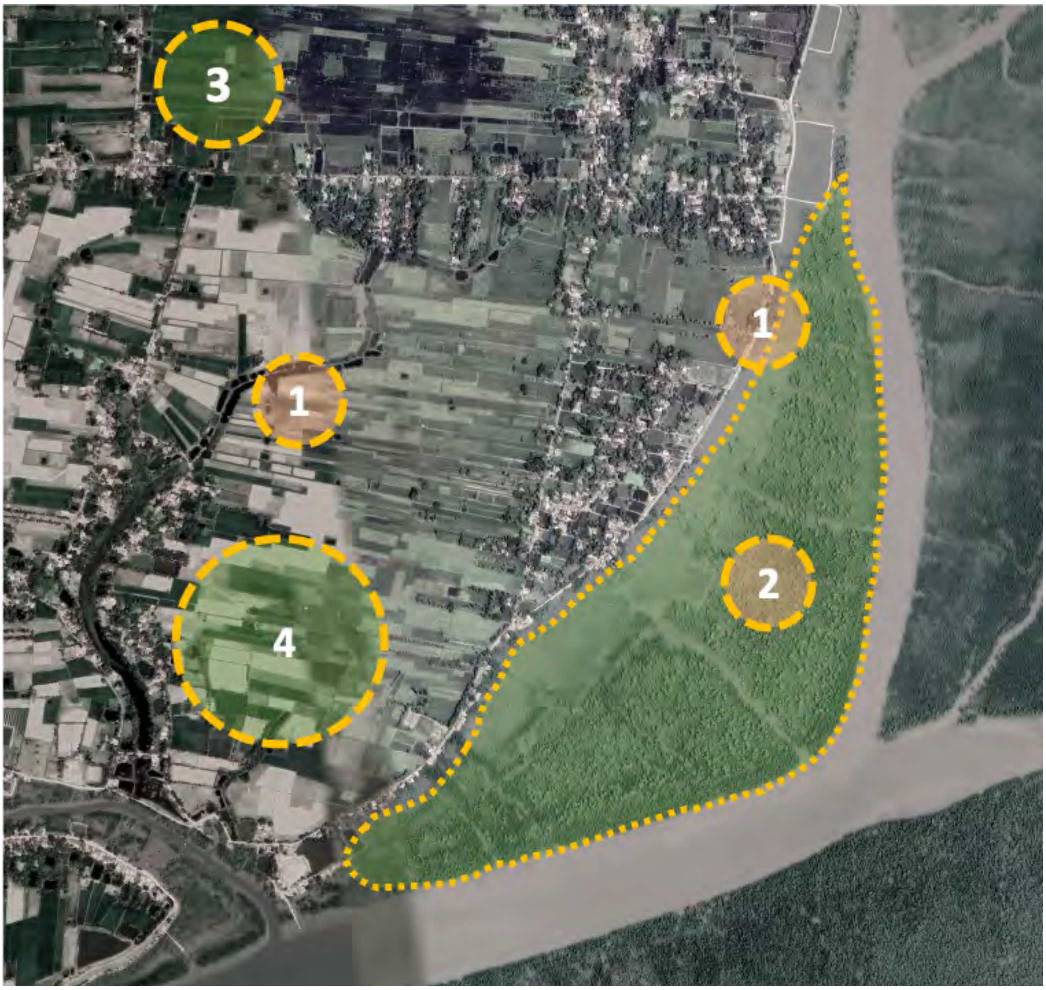
Riverine edges and mangroves

The area has many water bodies and small rivers, along with a high presence of mangroves and local varieties of bamboo along the river edge. Mangroves provide an effective natural buffer against storms, flooding and coastal erosion.


Rice cultivation

Mangrove plantation

RESOURCE MAPPING



1. Clayey soil

Clayey soil is dug out from riverbanks and agricultural fields to be used in the construction of flooring, plaster and walls.

2. Mangrove wood

Mangroves are locally available and are mostly used as wattle in wall construction. They are gradually declining because they are not replanted at the rate at which they are harvested.

3. Bamboo

Local bamboo is cultivated and is used for making roof structures and as wattle in wall construction. It is also sourced from other regions as the local supply doesn't meet the demand in the region.

4. Rice straw

Rice straw is a leftover from locally cultivated rice varieties. It is a commonly used material for thatch roofing.

TRADITIONAL BUILDING MATERIALS AND TECHNOLOGIES

I. Walls

TYPE 1: Wattle and daub walls

Bamboo, mangrove and other local wood varieties are used as wattle in the construction of walls. These walls are roughly 15 cm thick and plastered with mud daub. This is the predominant walling technology in the region.

TYPE 2: Sun dried bricks wall

Bricks are cut in the shape of parallelogram from the clayey agricultural soil and put out to dry. After drying, they are layered in courses. This type of technique is rarely found in the region now and only a few such houses remain.

II. Roofing material

TYPE 1: Flat clay tiled roof

Clay tiles are commonly used in the region. They require relatively lesser maintenance compared to thatch roofs.

TYPE 2: Thatched roof

Local rice thatch is processed and prepared for roofing. The thatch work requires periodic maintenance to counter wear and tear.

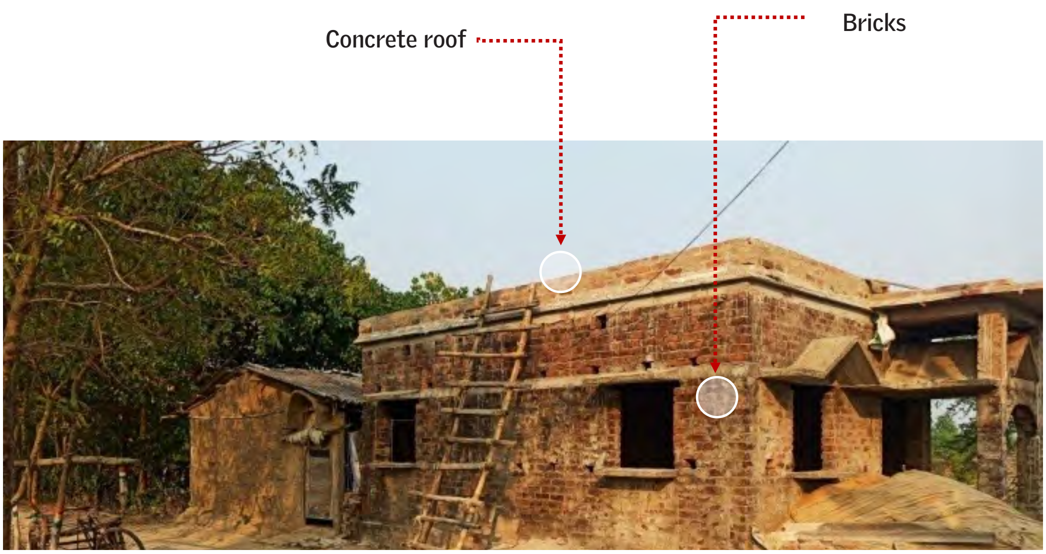
III. Intermediate floor

TYPE 1: Kadi Baraga floor

The Kadi (timber/bamboo beam) and Baraga (timber/bamboo rafter) are used as an intermediate floor for flat roof construction. The final flooring could be made with a mixture of soil and thatch or even with bricks in some cases.

TRANSITION: RENOVATIONS AND NEW CONSTRUCTION

Precast concrete column is the most common ‘transition material’ with many old constructions also preferring a hybrid system of precast RCC columns and wattle and daub walls. The roofing in most buildings is also transitioning at a fast pace from traditional thatched and tiled roofs to concrete, asbestos and galvanized iron sheets. The wattle and daub walls are being replaced by brick walls.



Bricks


Brick columns
Bricks


Asbestos sheets
Precast concrete posts

ADOPTION AND AVAILABILITY OF CONVENTIONAL MATERIALS AND TECHNOLOGY

An increase in the frequency of cyclones, floods and storms has contributed to the shift towards conventional techniques as they require relatively lesser maintenance. One can find multiple points of distribution for building materials like asbestos, bricks, cement and precast columns in the nearby towns; roughly up to 10–15 km from the village of Purb Shridharpur.

The residents of the village have started using some neo-sustainable technologies such as ferrocement shells and shallow domes for self-built houses in the village. This is a result of introduction of these materials and technologies as well as capacity building workshops facilitated by a local NGO working in the area.

Red bricks

Precast concrete distribution point

Locally manufactured bricks

Precast concrete columns

Ferrocement roof shells

Shallow dome roof

IMPACT OF ECONOMIC STRATA AND DWELLING LOCATION ON MATERIAL TECHNOLOGIES

The relationship between the location of households and economic class is evident in the area. Households located in the immediate proximity of the river are occupied by people who are mostly dependant on fishing for their livelihood and belong to relatively poorer communities. Households located away from the river are occupied by people who are more affluent. A consequence of this is that households near the river are affected the most by floods as the daub walls get washed off, thus exposing the wattle and creating holes in the wall. The main difference in built technology is the increase in the use of roof tiles in the affluent households.

Households situated in immediate proximity of the river

Residents living in immediate proximity of the river

Households situated away from the river

Residents living away from the river

VULNERABILITY TO CLIMATIC EVENTS

Houses are vulnerable to flooding about 2–4 times in a year. Water rises till about 900 mm above plinth for up to 48 hours. The region witnesses severe flooding once in 1 or 2 years resulting in increased maintenance issues. The area is also prone to cyclones which also causes similar repercussions on the people.

Flooding level (height) and impact on houses, near Purb Shridharpur

Impact of flooding on the wattle and daub walls

BUILDING TECHNIQUE:
SOIL-COW DUNG FLOORING

Demonstrated by mason
Mr Joy Mondal

Equipment required

Clayey soil, cow dung and bucket of water

Basic components to make the flooring include clayey soil, cow dung and water. All three of these components are abundantly available in the Sundarbans region.

The proportion of cow-dung and soil is dependent on local materials and requires a judgement by the person making the floor. However, the rest of the process is simple and does not require skilled labour. Maintenance requirements depend on the usage of the space and the footfall. An increase in footfall, especially with footwear, would result in more maintenance.

CONSTRUCTION PROCEDURE

Step 1

Clayey soil, cow dung and water is thoroughly mixed (in this case, a proportion of 1:2:2) so that it becomes homogenous. The mixture should be in a clayey state so that it can be spread over.

Step 2

The mixture is then taken by hand and placed in small mounds on the floor.

Step 3

The soil-dung mounds are placed at roughly equal distances in a grid so that they can be distributed evenly.

Step 4

The soil-dung mixture is then flattened into the ground and plastered thoroughly with hand.

Step 5

The floor is left to dry for 2-3 days.

BUILDING TECHNIQUE: THATCH PANELS

Demonstrated by mason:
Ms Neelima Halder

EQUIPMENT REQUIRED

Thatch, rope and split bamboo

Thatch is a by-product of the rice cultivation in the area. Split bamboo and rope are also materials that are locally available. Maintenance depends mainly on the rainfall received, and the wear and tear of these materials. Premium quality rice thatch is from a rice variety called *Dhudheshwar*. The other types are locally known as *Aman, Aush and Boro.*

CONSTRUCTION PROCEDURE

Step 1

The raw material for making the thatch is sourced from locally cultivated rice. The grass is cut at about 20 cm from the ground.

Step 2

The rice straws after the harvest are beaten and refined to make long strands which are held together in a bundle.

Step 3

The straw bundles are eventually placed along perpendicularly to two split bamboos and slid in between these two members.

Step 4

The bamboo bundle is folded back along the inside of the split bamboo member and tucked into it.

Step 5

Locally made ropes are used to tie the rice thatch to the split bamboos. The worker uses her leg to hold the thatch straight and tie the rope tightly so that it is held together.

Step 6

The panels are eventually stacked and kept protected from heavy rainfall. These are periodically made and distributed depending on local need.

BUILDING TECHNIQUE:
BAMBOO/WOOD ROOFING STRUCTURE

Demonstrated by local masons

EQUIPMENT REQUIRED

Saw

Machete

Needle

The basic components to make the roofing structure include bamboo, wood, ropes and thatching panels. All these components are harvested from the local vegetation and agricultural produce. Other tools involved in the construction process are machete, saw (to cut and place bamboo members) and a large threading needle (to thread the knots when the ropes are tied to the rafters). The process involves locally trained workers (self-taught/community learning) working for 5–7 days.

CONSTRUCTION PROCEDURE

Step 1

The bamboo framework is built on top of the base structure, which in this example consists of RCC columns and red bricks.

Step 2

The ridge member in the centre of the framework is put up first with few temporary supports after which the corner rafters are put up to hold it permanently in place.

Step 3

Purlins are placed next followed by the rafters. Each member once placed is tied together using locally made ropes.

Step 4

The thatched roofing is then stacked one over the other and each panel is tied to multiple rafters with ropes made from local straw.

Step 5

The thatch panels are then placed bottom-up with the first layer covering the lower portion of the roof. The process is repeated and continued till the entire roofing structure is covered.

Step 6

The bottom most edges of the thatch panel are trimmed to give it a clean look.

02

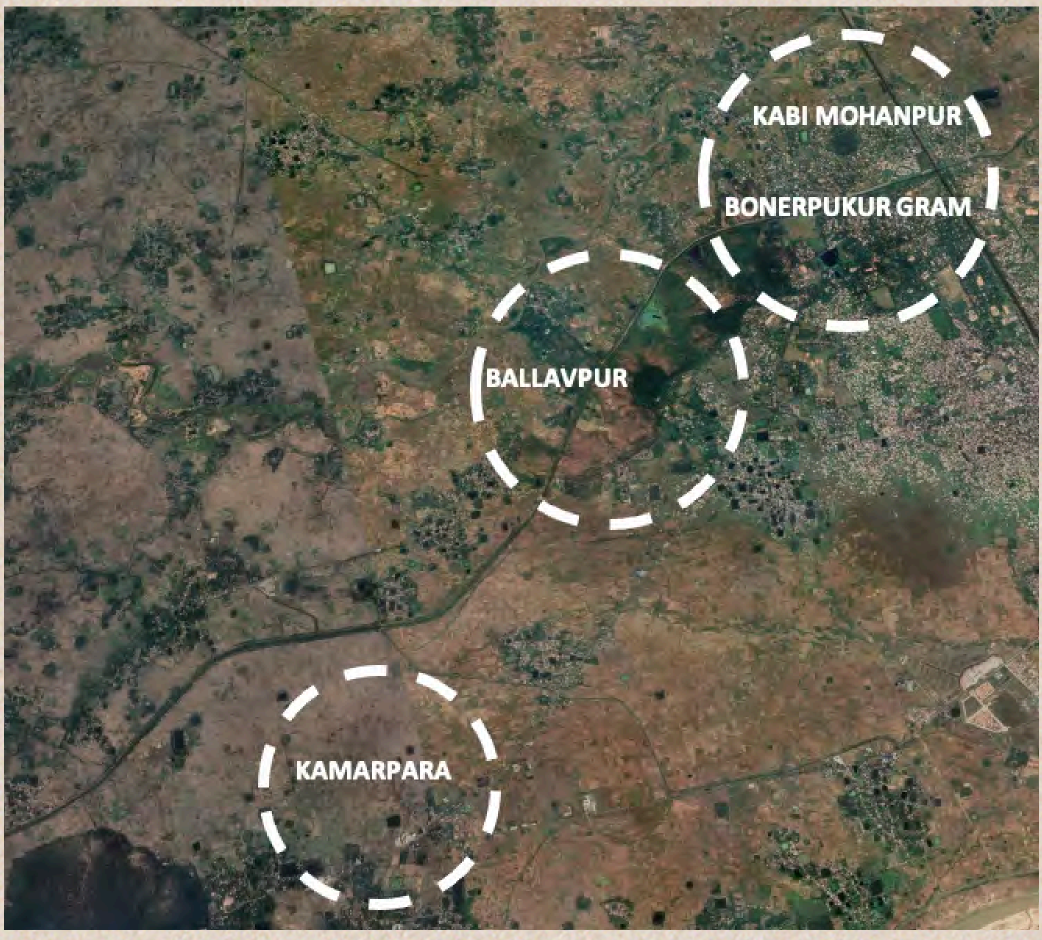
Bolpur - Birbhum

Location: 194 km from Kolkata

Geomorphological classification: Pediment-pediplain complex

Climate: Warm and humid

Context | Geography | Vegetation



Bolpur is a town located in the Birbhum district of West Bengal. The area is inland and relatively less affected by cyclones and floods than the villages closer to the sea or river.

Inland water bodies

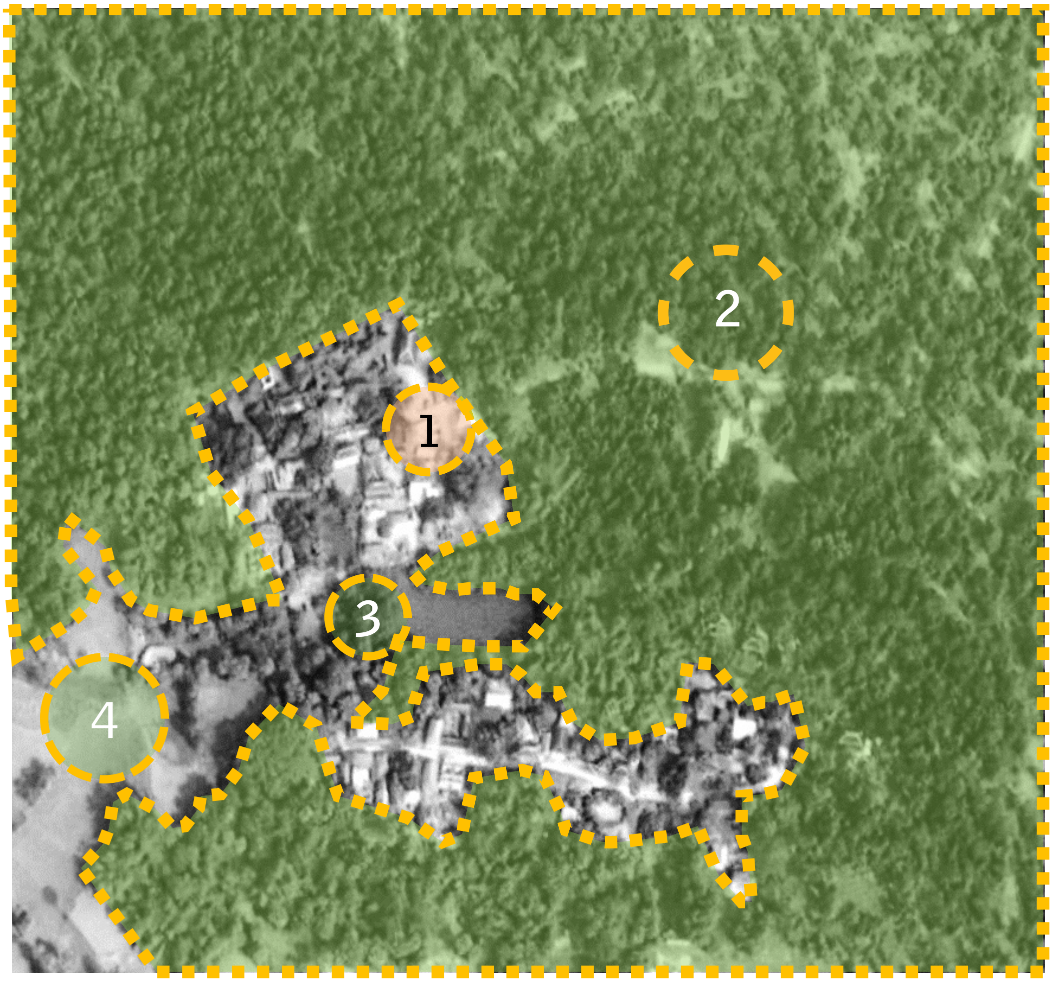
Forest areas around Bolpur

The soil found in and around Bolpur has a good proportion of sandy and clayey soil which is used to build cob walls for the dwellings in the region. This is unlike the wattle and daub technique which utilizes a mesh of wood or bamboo in the walls. Tal Gachh (palm tree), Sor grass, elephant grass and thatch from rice are varieties of local vegetation that are used in vernacular construction.

Sor grass along water channels

Typical soil house in the region

RESOURCE MAPPING



1. Coarse soil

Coarse soil from nearby areas is suitable for making cob walls.

2. Tal Gachh (Palm tree)

Wood from Tal tree is locally available in sizes of 10–14 feet. This wood is used as beams to span the rooms of dwellings. The size limitations of the wood also restrict the size of these rooms. Frequent cyclones bend the trees which makes the wood unsuitable to be used as beams.

3. Sor grass

The grass can be seen growing around water channels. It is cut and tied together to make bundles which are used as base for intermediate floors.

4. Rice thatch

Agricultural waste from locally cultivated rice varieties—Dhudheshwar, Aman, Aush, Boro—is commonly used as a material for thatch roofing.

TRADITIONAL BUILDING MATERIALS AND TECHNOLOGIES

I. Walls

TYPE 1: Layered soil walls (Cob walls)

Wet soil mixture is placed in layers for construction of a wall. The proportion and composition of the mixture which can include clay, sand, thatch, etc. depends upon the quality of the soil being used. Each layer requires around a day to dry off and hence the construction of the wall is a time taking process.

II. Roofing material

TYPE 1: Thatched roof

Local rice thatch is refined and prepared for roofing. The roof requires maintenance work once in a year.

III. Intermediate Floor

TYPE 1: Sor grass flooring

Bundles of locally available Sor grass are used for making intermediate floors. This is then layered with mud and thatch fibres for the final finish.

TYPE 2: Bamboo/ wooden flooring

Tal wood is used as the runner that spans the room and bamboo or wooden members are used above this. The mud and thatch mixture acts as the final finishing layer.

IV. Lintels/ Window frames

TYPE 1: Bamboo lintel

Small sections of bamboo are used as lintels above the windows to transfer the load of the wall above the window void.

TYPE 2: Wooden frame for triangular windows

The wooden frame around a triangular window essentially eliminates the need for a lintel with the frame itself transferring the load to the walls.

TRANSITION: RENOVATIONS AND NEW CONSTRUCTION

Bolpur lies in the inland region of West Bengal (away from the sea) and hence is less vulnerable to cyclones and flooding. The transition in villages around Bolpur is less stark as compared to relatively more vulnerable areas near the sea/river such as Purb Shridharpur in Sundarbans and Belari in Uluberia. However, the traditional thatch roof has been almost completely replaced by metal or asbestos sheets as thatch roof requires extensive maintenance once every year. The walls are being made with bricks, but this transition is slow and not widespread.


Asbestos roofing


Cemented plinth
Metal sheets
Concrete lintels
Brick walls

BUILDING TECHNIQUE: COB WALL

Demonstrated by local mason

Equipment required

Soil and water

The basic components to make walls includes soil (which includes clay and sand), water and sometimes thatch. All these materials are easily available in the Bolpur region. The proportion of water, clay, sand, and any other materials such as thatch or grass depends on the local soil properties and requires a judgement by the person making the wall. Mixing of soil and water is done using feet and the resulting semi-solid lump of mixture is placed in layers for construction.

The walls are plastered with mud. Maintenance requirements depend on surface moisture and development of cracks on the walls. In this type of wall construction, the cost of maintenance is low due to material availability in the vicinity.

CONSTRUCTION PROCEDURE

Step 1

Soil and water are mixed thoroughly using foot work in order to make the mixture homogenous. If the mixture requires additional straw, sand or clay, the mason will add them at this step based on his judgement and experience of the mixture at hand.

Step 2

Once the mixture is ready, a handful of the soil mixture is picked up by the mason. The mixture should be in a semi-solid state and not liquid.

Step 3

The lump of mixed soil is taken and placed on top of the previous layer of soil. One might require a ladder for this step.

Step 4

The lump of mixture is hand moulded to roughly fit the width of the wall.

Step 5

A bamboo stick is used on sides of the wall to even out the surfaces and to bring the lump into shape.

Step 6

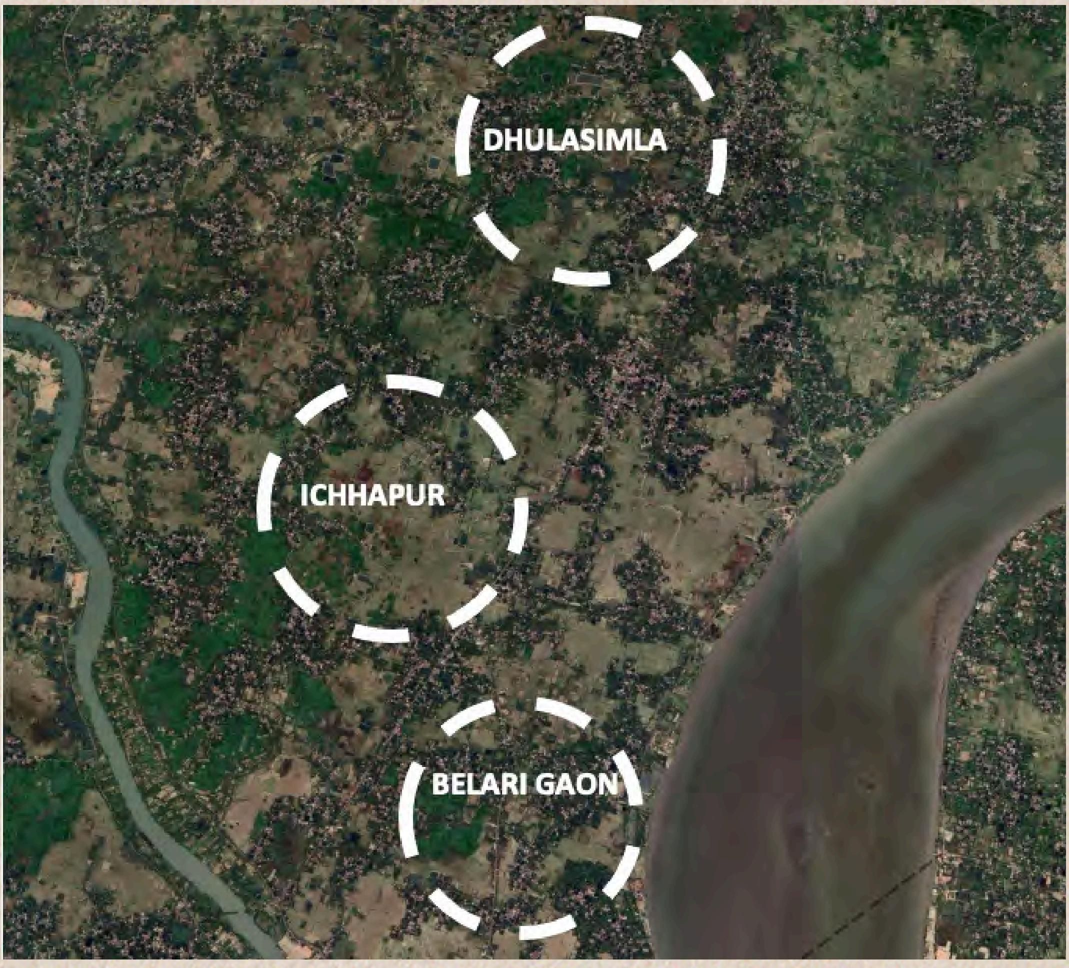
The wall is then left to dry, before applying another layer.

03

Belari village, Howrah

Location: 57 km from Kolkata
Geomorphological classification: Deltaic plain
Climate: Warm and humid

Context | Geography | Vegetation



Belari is a village located in the Howrah district of West Bengal. It lies on the western side of the Hooghly River and close to the Damodar River. The villages in this region are affected by the proximity to these two water bodies.

Inland water bodies and bamboo groves

Western bank of Hooghly River

The village of Belari and adjacent villages are close to the riverbed and the fertile soil found in the region is good for vegetation. The landscape is dotted with small water bodies and farms. Due to being close to Kolkata, the region has a high penetration of PMAY-G incentivized self-built housing.

Vegetation in the village

Houses in and around Belari village

RESOURCE MAPPING

1. Soil

Soil from the riverbed and fields is clayey in nature and is utilized for making daub in walls.

2. Bamboo

Local bamboo is used for making the wattle in walls.

3. Tree branches

Branches of local trees are also used as an under structure along with bamboo in walls.

4. Rice thatch

The rice thatch that is left over from rice cultivation is used in roofs or often mixed with soil to form plaster for walls.

TRADITIONAL BUILDING MATERIALS AND TECHNOLOGIES

I. Walls

TYPE 1: Wattle and daub walls with brick columns

Wattle and daub construction is prevalent in the area. The walls are most frequently used as fillers between brick columns. Bamboo and tree branches are used as wattle while a combination of soil and thatch is used as the daub.

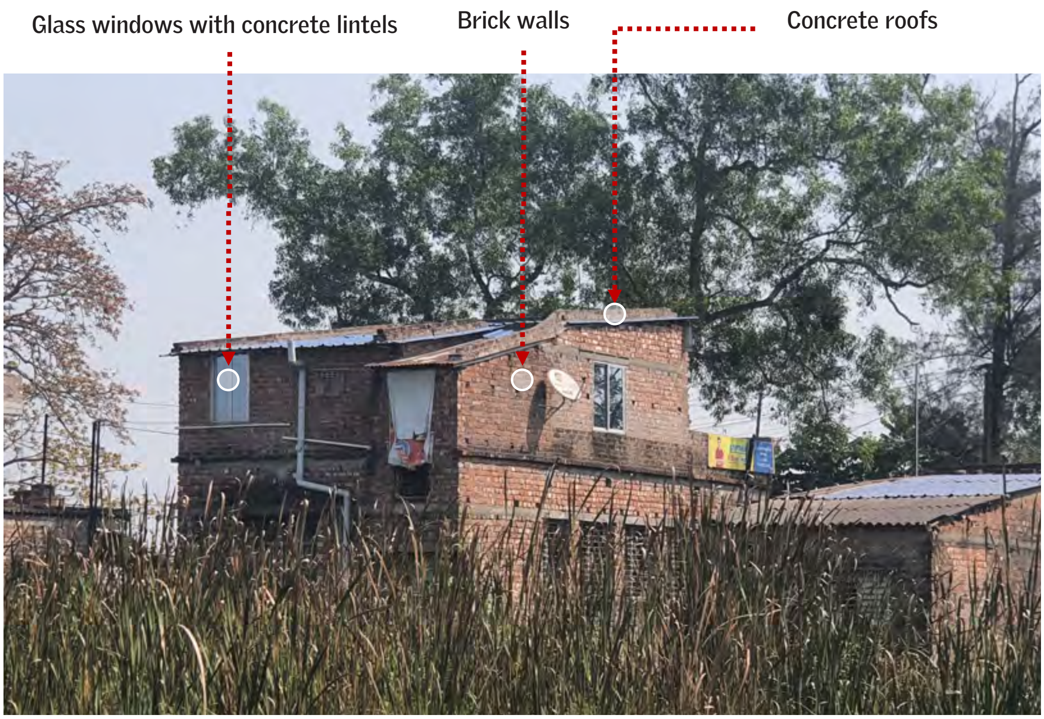
II. Roofing material

TYPE 1: Flat clay tiles

Flat tiles are abundantly used in the region even when the other parts of houses have shifted to conventional technologies. These tiles are supported by an under structure made of bamboo.

TRANSITION: RENOVATIONS AND NEW CONSTRUCTION

The village has almost entirely been taken over by brick-and-mortar construction with very few examples of local technologies remaining. However, the village still has many houses that use flat terracotta tiles as roofing material. Being very close to two rivers, the region is susceptible to flooding, which is a catalyst towards the transition to non-vernacular construction.

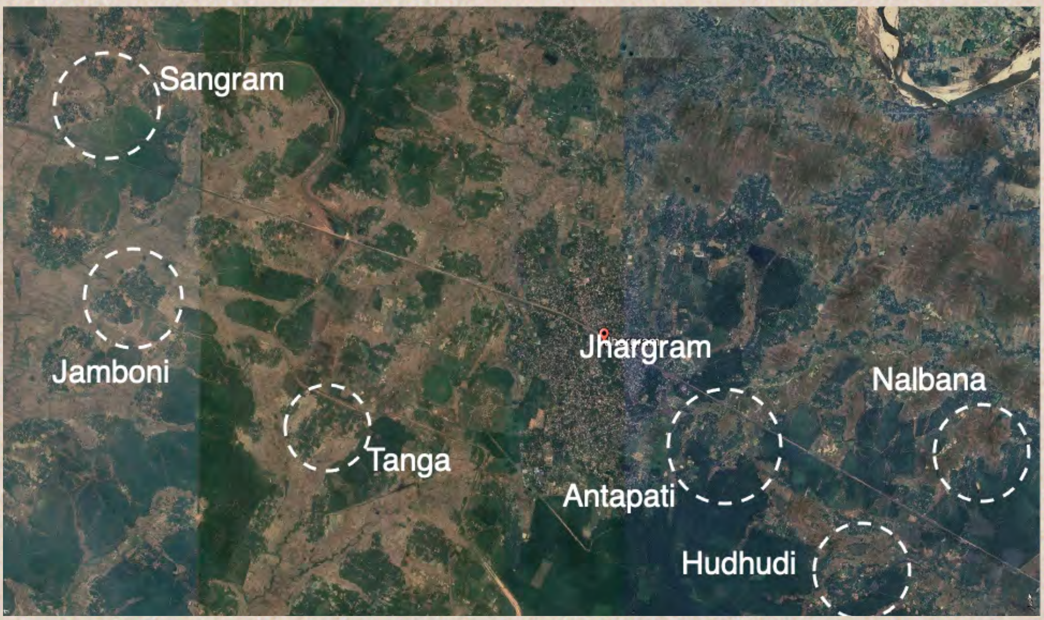


04

Jhargram town, Jhargram

Location: 175 km from Kolkata.
Geomorphological classification: Pediment - pediplain complex
Climate: Warm and humid

Context | Geography | Vegetation



The region is located between the Subarnarekha River in the south, the Kangsabati River in the north and has a topography of riverine plains that culminates in hills. The region lies in the low-damage risk Siesmic Zone II and away from the sea. It is relatively less prone to cyclones.

Forest area

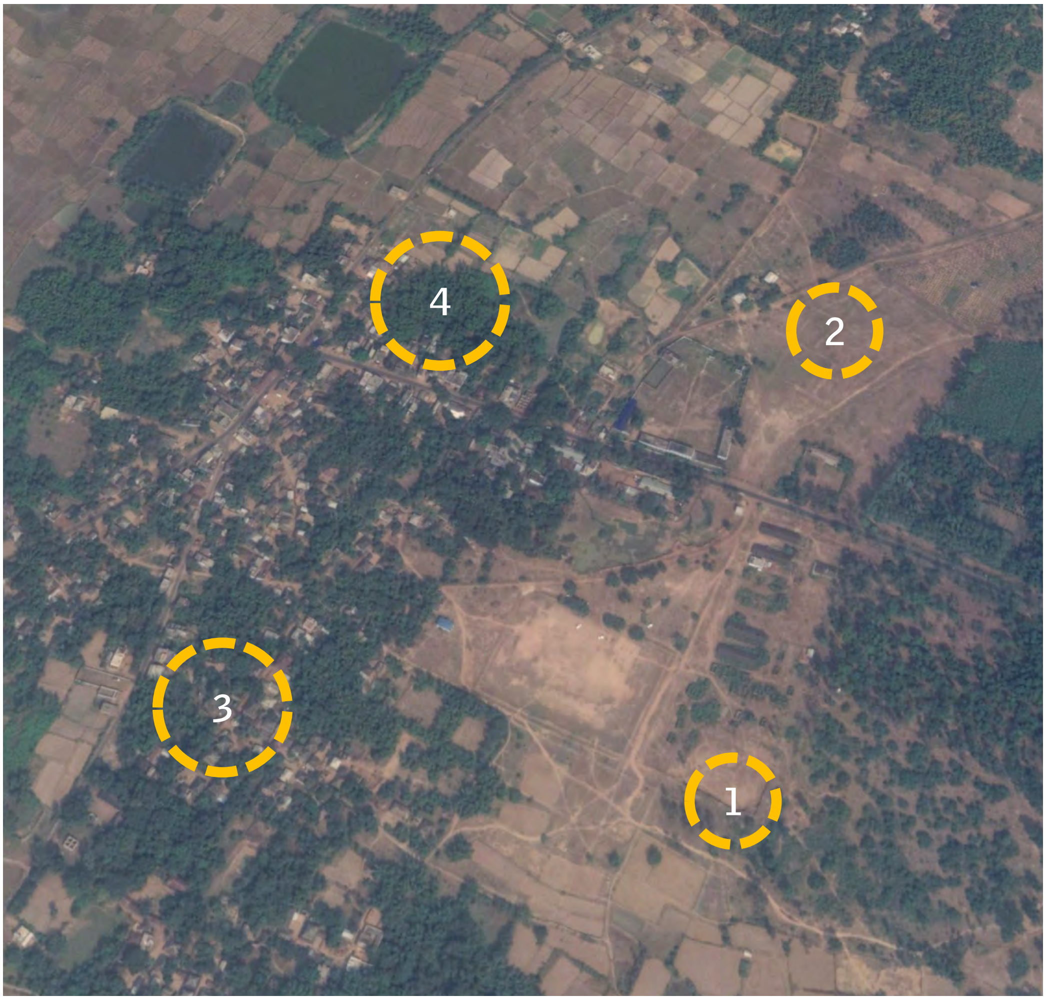
Inland water bodies present in the region

Vegetation such as bamboo, laurels, orchids, large creepers, Sal, Champac and Acacia are commonly found here. Most of the working population is involved in farming, dairy, and other daily labour jobs such as collection of forest timber and wild leaves, weaving, and other cottage industries.

Open farmlands

Typical village houses in the area

RESOURCE MAPPING



1. Rice straw from agricultural waste

The thatch used for construction comes from the straw that is left over from rice cultivation. This straw is processed before being turned into thatch for roof construction.

2. Soil

Clayey component of soil is used in making flooring and plaster while coarser soil is used in making cob walls. Soil is usually taken from fields or riverbanks for construction.

3. Neem, Sal, and other local varieties of wood

Columns, beams and roof frameworks are often constructed using Neem and Sal. Other varieties of native wood and bamboo are also used for the same.

4. Bamboo

Different thicknesses of native bamboo species are cultivated and used for various applications such as wattle in wall construction and roofing framework.

TRADITIONAL BUILDING MATERIALS AND TECHNOLOGIES

I. Walls

TYPE 1: Cob-based wall

Soil-based walls with thicknesses of roughly 45 to 60 cm are constructed by mixing fine and coarse soil types. This soil mixture is prepared by mixing soil with water, sand and, in some cases, thatch to increase the binding capacity and strength. Once the coursework reaches a foot or two high, it is allowed to dry before the next few courses are made. The walls are eventually plastered with mud.

TYPE 2: Wattle and daub

In this type of construction, roughly 15 cm thick walls made from local wood wattle and mud daub are constructed. These walls are periodically maintained as part of the annual festivities, which are then followed by painting with natural colours.

II. Roofing material

TYPE 1: Flat clay tiles

Flat clay tiles are sourced from nearby village or local markets. Even though these clay tiles have a higher wind resistance than thatch, they require maintenance as the tiles fly away and/or break in the extreme winds and rains that have increased in frequency over the last few years.

TYPE 2: Thatched roof

Rice straw, a by-product from rice cultivation, is used as thatch for roofing material. Thatch roofs are relatively less resistant to strong winds

III. Intermediate floor

TYPE 1: Bamboo/wooden flooring

Wooden members are used as supports that run along the span of the room and bamboo is laid on top of them. Soil and thatch are made into a homogenous mixture and used as the finishing layer on top.

TRANSITION: RENOVATIONS AND NEW CONSTRUCTION

The shift from thatched roofing to asbestos or galvanized iron sheets is the most predominant building material transition in and around the town of Jhargram. Transition to conventional materials is more observable in villages that are closer to Jhargram. Damage by elephants and rodents is another reason for people to shift towards stronger materials such as brick and concrete.

Column beam structure, concrete roofs and hollow bricks

Asbestos

05

Purulia town, Purulia

Location: 298 km from Kolkata
Geomorphological classification: Pediment - pediplain complex
Climate: Warm and humid

Context | Geography | Vegetation

Purulia is located to the north of the Kangsabati River. This region is in the eastern part of the Chota Nagpur Plateau which is an undulating land with scattered hills. There are multiple small villages with high tribal population along the Ajodhya hill range that lies within the plateau.

Open farmlands with adjacent water bodies present in the region

Forest area in the region

Housing cluster in the region

Brick kilns in the region

Majority of the population is involved in collection of wood, Sal leaves and edibles such as fruits, honey, etc. from the forest. Agriculture and daily labour jobs in small cottage industries are also a major source of employment. Most parts of the region experience relatively high temperatures and face extreme draught during summers.

RESOURCE MAPPING

1. Rice straw from agricultural waste

The straw obtained as a by-product of rice cultivation is used as roofing material. It is collected and husked manually before being dried in the sun.

2. Natural stone

The highlands and mountains of the region are rich in natural stones which can be found on the surface or with minimal digging.

3. Neem, Sal and other local varieties of wood

Local timber such as Sal and Neem are sourced from nearby forests. They are predominantly used for making door-window frames, panels, beams and roofing frameworks.

TRADITIONAL BUILDING MATERIALS AND TECHNOLOGIES

I. Walls

TYPE 1: Cob walls

Mixture of fine and coarse soil, water and straw is used for making cob-based walls. Lumps of the mixture are made from the mix which are stacked in courses. Once the coursework reaches a foot or two high, it is allowed to dry over before the next few courses are made. The thickness of the walls ranged from a foot to a foot and a half.

TYPE 2: Random rubble with mud mortar

Differently shaped stones with mud mortar are used for building walls and columns which are finished with a mud plaster. Several buildings made from random-rubble masonry have been standing for over 50 years.

II. Roof

TYPE 1: Curved clay tiles

Curved clay tiles locally known as *Khoppar* are laid one on top of another. They are manufactured from local clayey soil. They are sourced from local tile makers from nearby villages.

TYPE 2: Thatch roof

The thatch roof produced from rice straw provides good thermal comfort by insulating the interiors from harsh sunrays. However, they are vulnerable to catching fire in the extreme summer heat. They also get damaged from the strong monsoon rains and require periodic maintenance.

TYPE 3: Flat clay tiles

Flat clay roof tiles are more resistant to strong winds when compared to a thatched roof. The tiles are laid on the purlins in such a way that they overlap with each other.

BUILDING TECHNIQUE: RANDOM RUBBLE MASONRY WALLS

CONSTRUCTION PROCEDURE

Step 1

Different stone sizes are used in wall construction. Larger rocks are collected and broken down into smaller easier-to-handle pieces.

Step 2

Mud mortar is prepared by mixing clayey and coarse soil with water.

Step 3

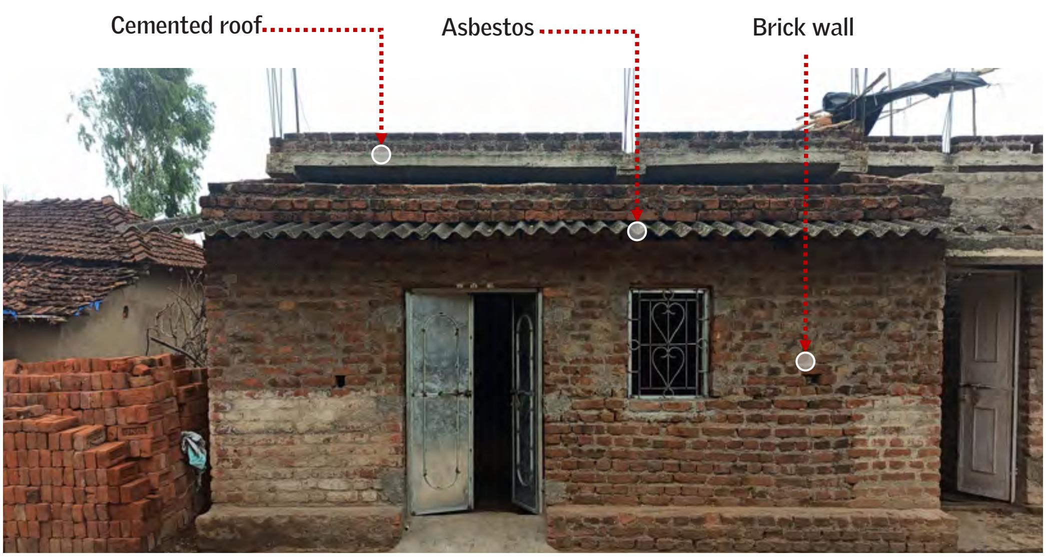
For constructing the walls of the house, random rubble stones are laid layer by layer by using mud mortar as binding material.

Step 4

During the construction phase, timber or bamboo-based support structures are provided for placing roofing framework as well as lintels for door and window frames.

TRANSITION: RENOVATIONS AND NEW CONSTRUCTION

The villages closer to Purulia are rapidly transitioning from traditional to conventional construction. In the rural outskirts, much of this material transition in self-built houses is due to government sponsored housing schemes which incentivize conventional materials. Tribal communities are also unable to access nearby forests as these locations are government protected reserves now. This stops them from collecting material from the forest which was earlier easily accessible for building construction.



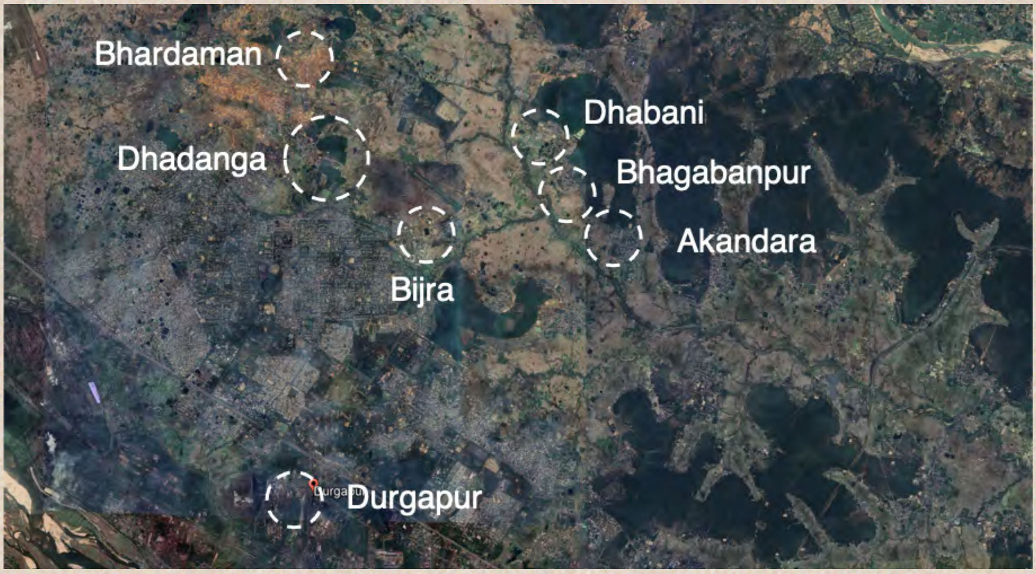

Asbestos

06

Durgapur town

Location: 172 km from Kolkata
Geomorphological classification: Pediment - pediplain complex
Climate: Warm and humid

Context | Geography | Vegetation



Durgapur, one of West Bengal's largest planned industrial hubs, is located in Paschim Bardhaman district, on the banks of the Damodar River. Until recently, the area was densely forested and remnants of the old Sal and Eucalyptus forests can still be found.

Forest area of the region

Farmlands present in the region

Typical traditional housing clusters in the region

The villages in the outskirts of the town are located along agricultural lands and the region in general has relatively low vulnerability to natural disasters. A large proportion of the population in the villages are employed through the industries in the area while the remaining population is involved in agriculture and daily labour jobs in small scale industries.

RESOURCE MAPPING

1. Rice thatch from agricultural waste

The thatch used for making roofs is obtained by processing the by-product from the cultivation of rice. They are dried and made into bundles which are then used as thatch for the roof.

2. Soil

Soil found in these riverine alluvial plains is one of the major materials used for construction of walls and flooring. It is usually sourced from farmlands or nearby areas which have a high presence of clayey soil.

3. Mango tree, Sal, date palm and other local varieties of wood

Wood is mainly used for the construction of elements such as columns, beams and roof frameworks. It is also used for making door and window frames and panels. Common types of wood used are of Neem and Sal trees. Other types of local wood are also used, such as date palms and mango trees that are sourced from the surrounding areas.

4. Bamboo

Bamboo is majorly used for making structural frameworks for walls and roofs. It was previously used for making partitions, wall construction and doors. But its use has reduced over time.

TRADITIONAL BUILDING MATERIALS AND TECHNOLOGIES

I. Walls

TYPE 1: Cob-based wall

Walls are constructed by mixing clayey and sandy soil with water in appropriate proportions. The construction procedure is carried out course by course with the wall thicknesses going from a foot to even up to two feet in some cases. Mud mixture is used to plaster these walls, which require periodic maintenance as cracks develop in the heat.

II. Roof

TYPE 1: Flat clay tiles

Flat clay tiles are used as a roofing material. This material is more durable than thatched roofs and requires lesser maintenance.

TYPE 2: Thatched roof

Agricultural by-products, and in some cases leaves, are used for making thatched roofs. Thatches are subject to wear and tear by rain and wind, as well as susceptible to fires. These thatches must be maintained on a periodic basis.

BUILDING TECHNIQUE: COB WALL

Step 1

The soil required is excavated from nearby sites. The mixture made for construction is a combination of clayey and sandy soil with water.

STEP 2

A spade is initially used to mix the components and further mixing is carried out through footwork.

STEP 3

It is mixed until a homogenous mixture is obtained and is spread out on the ground as a bed thoroughly using a spade tool.

Dividing the mixture into one-foot-thick rows by footwork

Dividing and creating spherical lumps by hand

Maintaining the semi-clayey state of the lumps by sprinkling water

STEP 4

The mixture on the ground is then divided into roughly 30 cm thick rows using feet. These rows are further divided into lumps by hand. Water is sprinkled on them to maintain the wetness of the lump of mixture.

Placing of soil lumps onto the wall

Evenly spreading and shaping the soil mound using hand

STEP 5

The prepared lumps of soil are placed one after the other to create a uniformly thick lateral layer on top of the previously made layer. It is then evenly spread and shaped using hand.

STEP 6

The evenly spread mixture on the wall is further flattened and smoothened using hands and a flat wooden stick. Once the process is complete, the wall is left to dry for two to three days.

TRANSITION: RENOVATIONS AND NEW CONSTRUCTION

The establishment of Durgapur Steel Plant has led to faster urbanization of the town and nearby areas. This has led to an increased use of conventional building materials, a flourishing demand-supply chain for these materials and ultimately an increased pace of transition from traditional building materials to conventional buildings.

Chapter 4

Case studies

DOCUMENTATION AND RESOURCE MAPPING OF TRADITIONAL TECHNOLOGIES IN ODISHA

Puri coast: Puri

Location: 80 km from Bhubaneswar

Geomorphological classification: Coastal plain

Climate: Warm and humid

Context | Geography | Vegetation

The Puri coast is around 75–80 km from the city of Bhubaneswar. This coastal region receives strong torrential rains as compared to most other regions in Odisha. The land is fertile and ideal for cultivation because of the presence of multiple water bodies. The resident population is dependent on the sea and coastal plains for their livelihood, practising rice and betel nut cultivation along with fishing and fish farming. Puri lies in Seismic Zone III, which is a moderate risk zone according to Odisha State Disaster Management Authority.

Coastal plains where fish farming and agriculture is practised

Road on bunds in between the paddy fields in the region

The region lies in a zone which is highly vulnerable to extreme natural events such as high velocity winds blowing at 30 m/s and cyclonic storm surges accompanied with heavy rain. Trees such as Akasya and Jheong are abundantly found in the region and help in providing a certain level of resistance to the sea winds and cyclones. However, the population has started to settle away from shore in recent years due to the increase in extreme climatic events.

Pine groves near the sea

Rice and coconut cultivation

RESOURCE MAPPING

1. Laterite

Laterite mining is legally prohibited in the area but is still used in the region. It is mainly used for plinths and columns.

2. Pinewood and Akasya

Pinewood, Akasya and Jheong trees are found in the region and their wood is used to make columns, rafters, purlins and even used in wattle and daub construction.

3. Coconut and rice farming

The agricultural by-products of coconut and rice farming, respectively timber and thatch, are processed and used for construction. The timber is used for supports and frameworks and the thatch for roofing.

4. Soil

The soil from the riverbanks and agricultural lands in the coastal plains is used for making cob-based walls and used in wattle and daub walls.

TRADITIONAL BUILDING MATERIALS AND TECHNOLOGIES

I. Walls

TYPE 1: Wattle and daub

Local varieties of wood and bamboo are used as wattle while the soil mixed with water is used as daub to make walls of roughly 15–25 cm in thickness. The daub develops cracks in the heat and falls off with wear and tear from the torrential rains, and hence requires periodic maintenance.

TYPE 2: Cob wall

Soil from the construction site or nearby land is mixed with cow dung, water and straw to make a homogenous mixture for constructing walls. Lumps of this mixture are placed as a layer of roughly 35–45 cm thickness and left to dry before the next layer is placed on top of it.

TYPE 3: Laterite stone

Laterite is an abundantly available stone in the region and has been traditionally used for building walls and plinths.

II. Roofs

TYPE 1: Flat clay tiles

Flat clay tiles are locally manufacturd or sourced from nearby local markets in the region. The tiles are more resistant to the strong winds and torrential rains in the region, than thatched roofs and hence requires less maintenance than the latter.

TYPE 2: Straw thatch roof

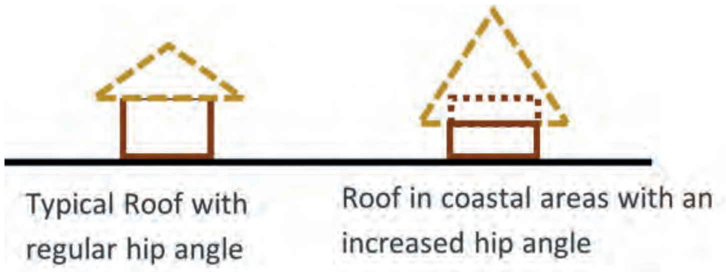
Agricultural waste is treated to make thatches for roofing. The thatch requires periodic maintenance from wear and tear, as it eventually gets damaged from rains and winds.

CONSTRUCTION TECHNIQUE AS A RESPONSE TO CLIMATE: ROOF

Thatched roof with fishing nets layered over it

Fishing nets, tied over roof structures

Fishing nets are tied to the end of the rafters over the thatched roofs. The roof is also made with an increased hip angle. Orientation of the built structures with the longer side of the building along the direction of the wind is another noticeable adaptation to the wind pattern in the region. These techniques help in providing a certain degree of wind resistance.

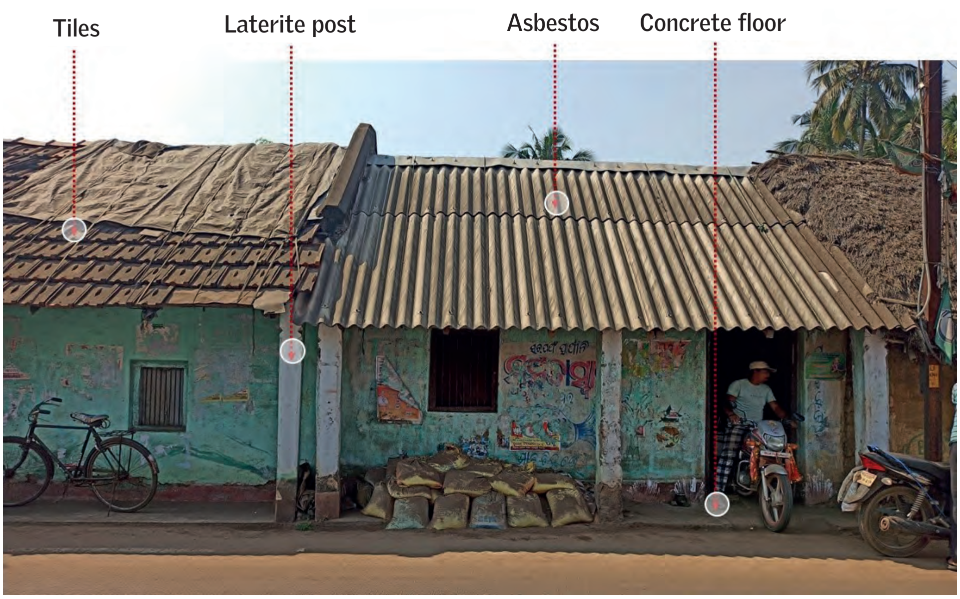


Pitched roof with increased slope and longer side of the building aligned with wind

Building with increased slope of roof, which is a common feature in most of the vernacular housing in the coastal region

TRANSITION: RENOVATIONS AND NEW CONSTRUCTION

Precast concrete column is the most common ‘transition material’ with many old constructions also preferring a hybrid system of precast RCC columns and wattle and daub walls. The roofing in most buildings is also transitioning at a fast pace from traditional thatched and tiled roofs to concrete, asbestos and galvanized iron sheets. The wattle and daub walls are being replaced by brick walls.

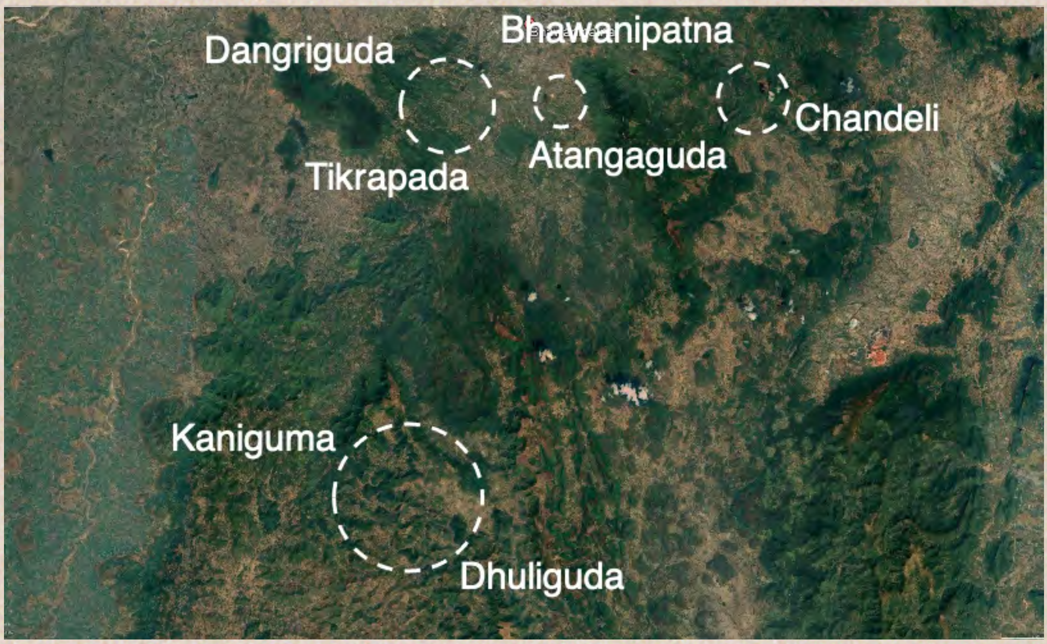


02

Bhawanipatna town

Location: 423 km from Bhubaneswar
Geomorphological classification: Moderately dissected hills and valleys
Climate: Warm and humid

Context | Geography | Vegetation



Bhawanipatna is a town and district headquarters of the Kalahandi district of Odisha. It lies in between a series of hills and valleys which are part of the western rolling uplands topographic zone. The outskirts of the town are mostly farmlands, forested areas and hills.

The region has high water runoff owing to its topography and hence low risk of flooding. The villages in the outskirts of Bhawanipatna are located mostly in the valleys and plains. There is a series of villages within the forest consisting of 30–40 houses each. Most of the construction in these villages is carried out by the resident population themselves, rather than by masons.


Farmlands area


Rice and palm cultivation

Mud wall and thatch roof housing, found in the tribal villages of the region

Typical traditional housing cluster in the region

RESOURCE MAPPING

1. Rice straw

Straw from locally cultivated rice is commonly used as a material for making thatches for roof. It is processed, dried in the sun, and then made into bundles.

2. Timber

Neem and Sal are sourced from the nearby forests and are mainly used for making columns, beams, lintels, door-window frames, and roofing framework. Other varieties of local wood are also used for making the same.

3. Bamboo

Different varieties of local bamboo are collected from the forest and in some cases cultivated in small pockets of forested areas as well as farmlands. This bamboo is sold in the local market and used for construction purposes.

TRADITIONAL BUILDING MATERIALS AND TECHNOLOGIES

I. Walls

TYPE 1: Cob wall

Fine and coarse soil is mixed to make cob-based walls of roughly 30–40 cm thickness. They are layered in coursework and are finished with mud plaster.

TYPE 2: Wattle and daub

Local bamboo is used as the wattle while the soil mixture is used as daub. The walls are roughly 15 cm in thickness. This type of construction requires periodic maintenance as the mud daub cracks in the summer heat and gets dislodged by floods.

II. ROOFS

TYPE 1: Curved clay tiles

Curved clay tiles are locally made or sourced from nearby villages. The tiles require maintenance from time to time due to wear and tear.

III. Intermediate floor

TYPE 1: Bamboo-wood floor

Palm or Sal wood are used as runners that span the room wall to wall while bamboo or other local wood is placed on top of them. The mud and thatch mixture acts as the final layer on top of this framework.

IV. Screens

Local thatch from palm and coconut leaves is used to weave mats and screens. They provide a certain degree of protection primarily from wind, rains and the extreme summer heat. They also act as curtain-like envelopes for extended semi-private living spaces such as verandas and storerooms.

TRANSITION: RENOVATIONS AND NEW CONSTRUCTION

Bhawanipatna is located in the hilly inlands of Odisha, away from the sea. Hence, it is less vulnerable to cyclones and flooding. However, traditional roofs have been almost completely replaced by metal or asbestos sheets as thatch and tiled roofs require maintenance. Traditional mud walls are also being replaced with conventional brick walls. Mud mortar is used as a substitute for cement mortar in the construction of some of these dwellings.

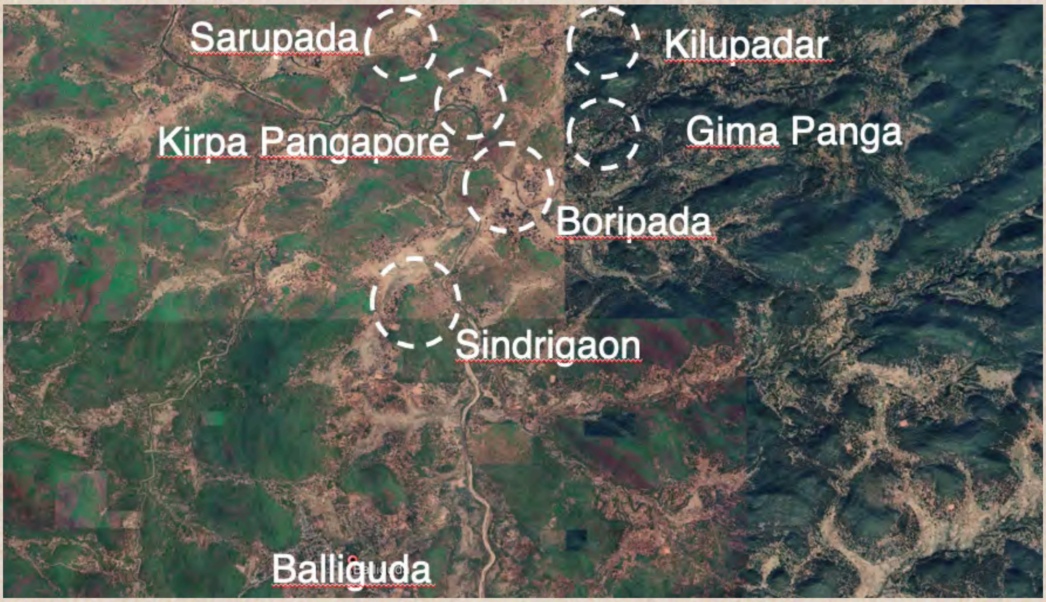
03

Balliguda and Phulbani: Kandhamal

BALLIGUDA

Location: 267 km from Bhubaneswar
Geomorphological classification: Pediment - pediplain complex
Climate: Warm and humid

Context | Geography | Vegetation



Balliguda is a town in the Kandhamal district of Odisha. It is located about 53 km west of district headquarters, Phulbani. The region has an undulating topography of mountains and highlands, and is home to a large tribal population. The majority of the population is involved in farming, dairy, and daily labour jobs such as collection of forest timber, collection of wild leaves, weaving, thatching and as helpers in mills, kilns and other cottage industries.

Forest in the region

The region has several inland streams running from the hills through the low-lying valleys making the land fertile. The area is rich in natural forest cover and the residents have been dependent on resources from nearby forests to construct houses. Currently they face issues of resource collection as the area is now considered a reserved forest zone.

Inland streams

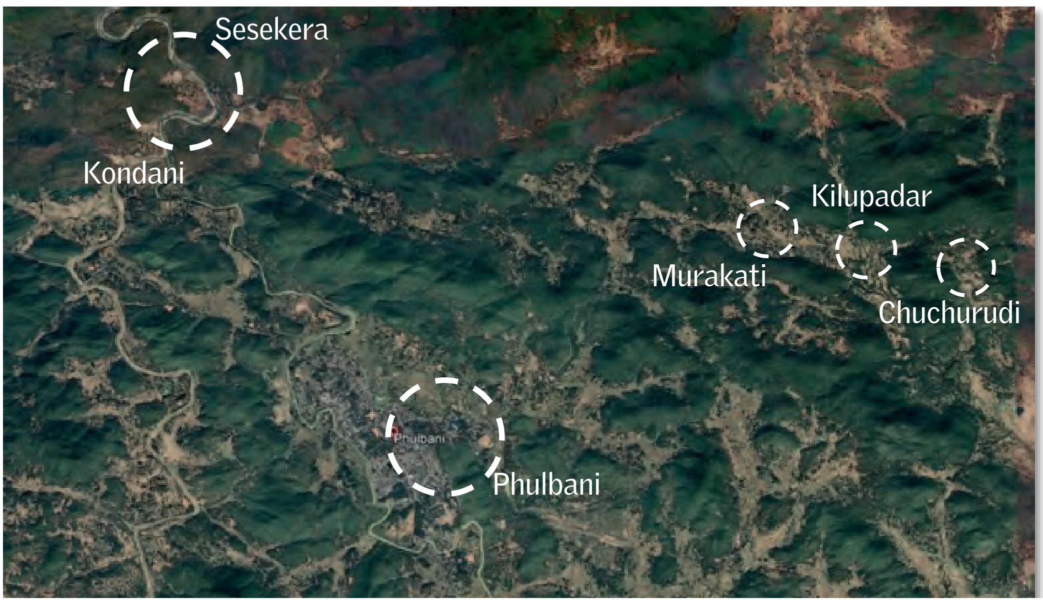
Agricultural fields at the foothills of mountains

Typical village cluster with houses

PHULBANI

Location: 211 km from Bhubaneswar and 165 km from Berhampur.
Geomorphological classification: Low dissected hills and valleys
Climate: Warm and humid

Context | Geography | Vegetation



Phulbani is a municipality and administrative headquarters of Kandhamal district. The region has a wide variety of flora and fauna as it is surrounded by forests. It has a mountainous topography. Salunki River and several waterfalls cross through the hills and valleys in the region.

Agricultural field

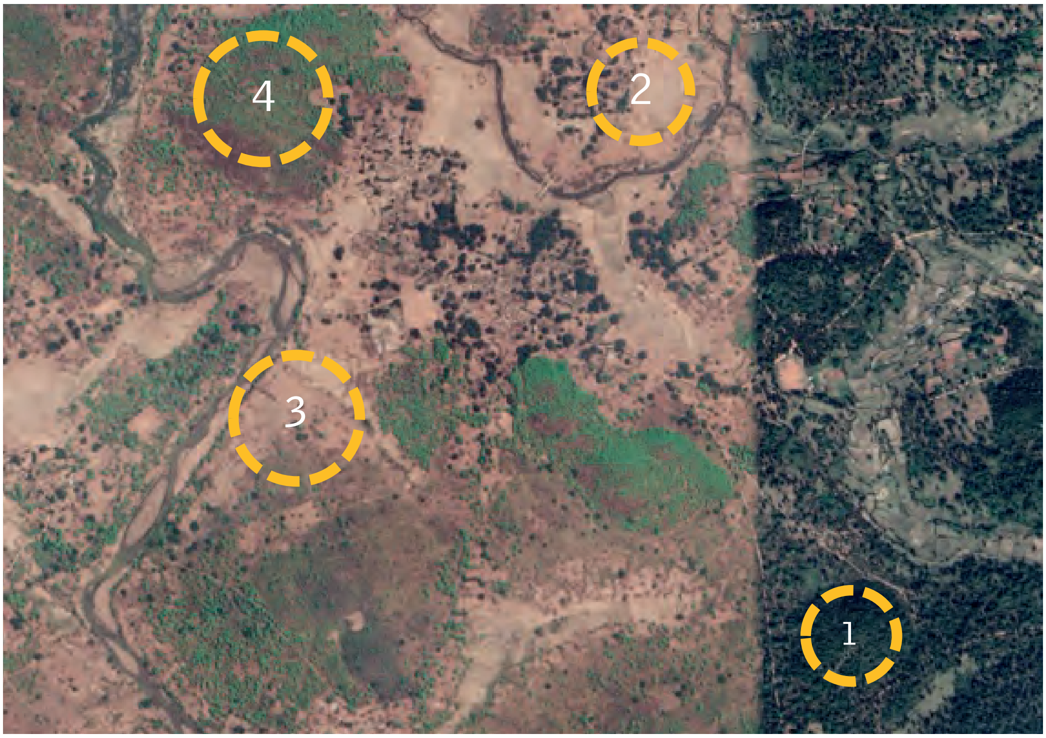
Forests in the region

River Salunki that flows through the region

Typical mud and thatch house, found in the villages

Although there is a good rainy spell from June to September, there is high water run off due to the hilly terrain and therefore the area does not experience flooding. Most of the villages in the outskirts of the town are along the valleys. The main occupation of the people is farming and other daily wage labour such as collection of forest timber and wild leaves.

RESOURCE MAPPING



Resource mapping in Balliguda

Resource mapping in Phulbani

1. Timber
Local timber is used relatively more frequently as a building material for construction than in most other locations under this study. The reason for it is the easy availability of it as it is sourced from nearby forests. Timber is used for fencing, wood wattle in walls, lintels, columns, beams, and roofing framework.

2. Soil
Soil is sourced either from the land near the construction site and/or from local agricultural land. Coarse and fine soil is mixed with water to form a homogenous clayey mixture which is used to make cob-based walls.

3. Rice straw
The thatch which is a by-product from the cultivated rice is processed, dried and then made into bundles of straw. These bundles are used as a common material for thatch roofing.

4. Palm tree
Wood and thatch from palm trees are locally sourced as they grow abundantly in the area. This wood is used as rafters, lintels and beams in dwellings.

TRADITIONAL BUILDING MATERIALS AND TECHNOLOGIES

I. Walls

TYPE 1: Wooden panel with mud plaster

These walls are made of local wood panels and the edges are sealed with a mud mixture made from clayey soil and water. These walls are about 5–10 cm thick. There are very few houses remaining in the area that use this technology.

Type 2: Cob walls

Fine and coarse soil are mixed with straw and water to make walls of roughly 30–45 cm thickness. They are plastered with mud and require periodic maintenance as they are prone to cracking.

II. ROOFS

TYPE 1: Curved clay tiles

Curved clay tiles are made by moulding clayey soil and burning them in a kiln. They require relatively lesser periodic maintenance compared to thatched roofs. A small projection is made on the tile placed at the eve to hold the tiles which are stacked behind it. These are locally made or bought from tilemakers from nearby villages.

TYPE 2: Flat clay tiles

Flat clay tiles are sourced from local markets. The tiles require maintenance when they get damaged from strong winds or rains but have relatively higher resistance than thatch. The tiles are made in such a way that a part of the tiles gets overlapped one over the other.

TYPE 3: Thatch roof

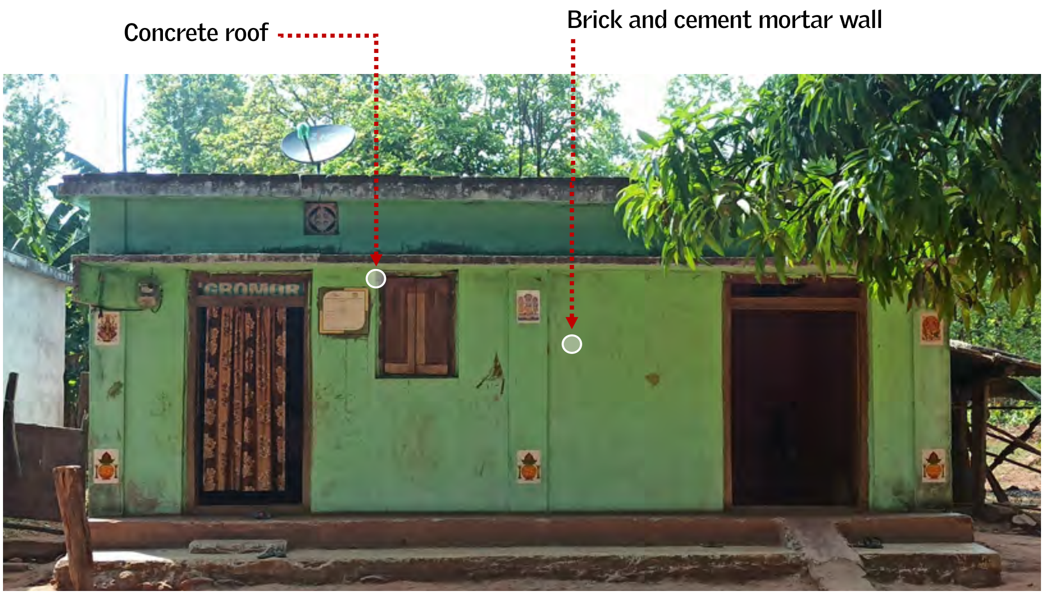
Thatch is made from agricultural by-products of rice cultivation and used for roofing. The region has another kind of thatch roof which is made from leaves and often paired with rice straw thatch.

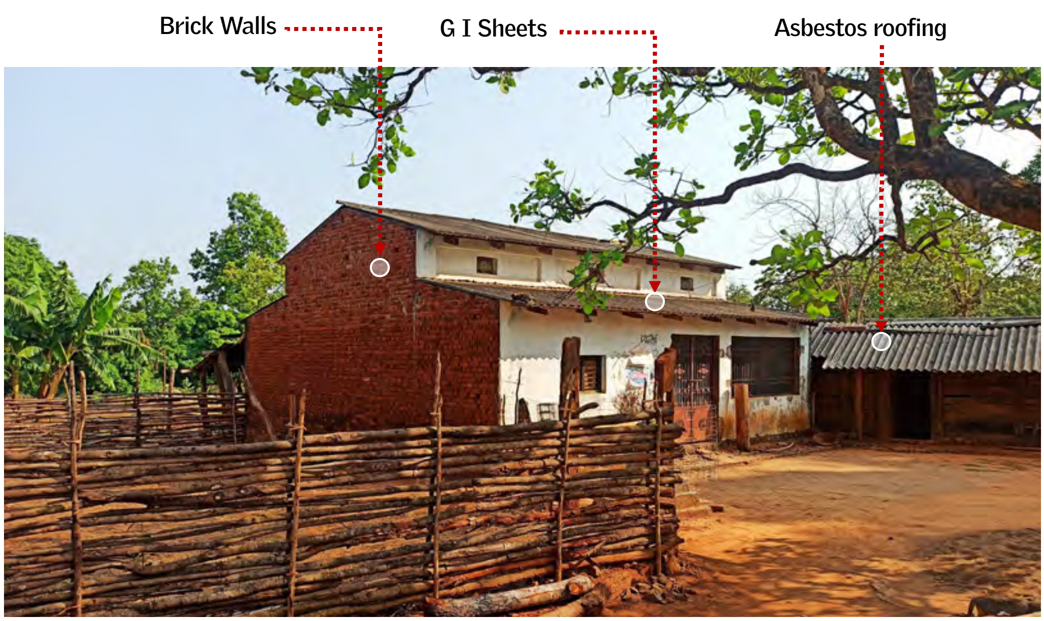
TYPE 4: Sal leaf and rice thatch roof

A combination of Sal leaf layer is placed over rice thatch and used for roofing. In some houses, broad leaves such as that of Sal leaves are weaved together and then layered on top of the base layer of thatch. These double layered thatches help in providing better insulation and provide protection from rain and winds.

TRANSITION: RENOVATIONS AND NEW CONSTRUCTION

Even though soil-based walls are replaced with conventional bricks and cement plaster, the most dominant change is observed in the roofs as their construction has moved from vernacular technologies like thatch and tiles to asbestos and concrete. A large proportion of the transition is facilitated through the government housing schemes in these villages.

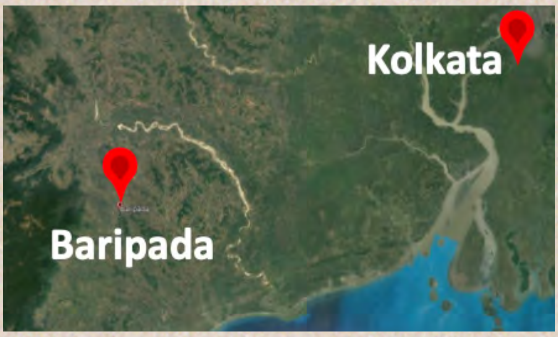




04

Baripada and Bisoi in Mayurbhanj district

BARIPADA



Location: Mayurbhanj district, 223 km from Kolkata
Geomorphological classification: Alluvial plain
Climate: Warm and humid

Context | Geography | Vegetation

Baripada is a town located in the Mayurbhanj district of Odisha. The region has a topography of mountains and highlands with rivers passing near it. The region has a high proportion of tribal population which is mostly involved in agriculture and daily labour jobs such as weaving, thatching, making leaf plates, collection of forest timber, leaves, etc.

Local vegetation such as Neem and Salwood

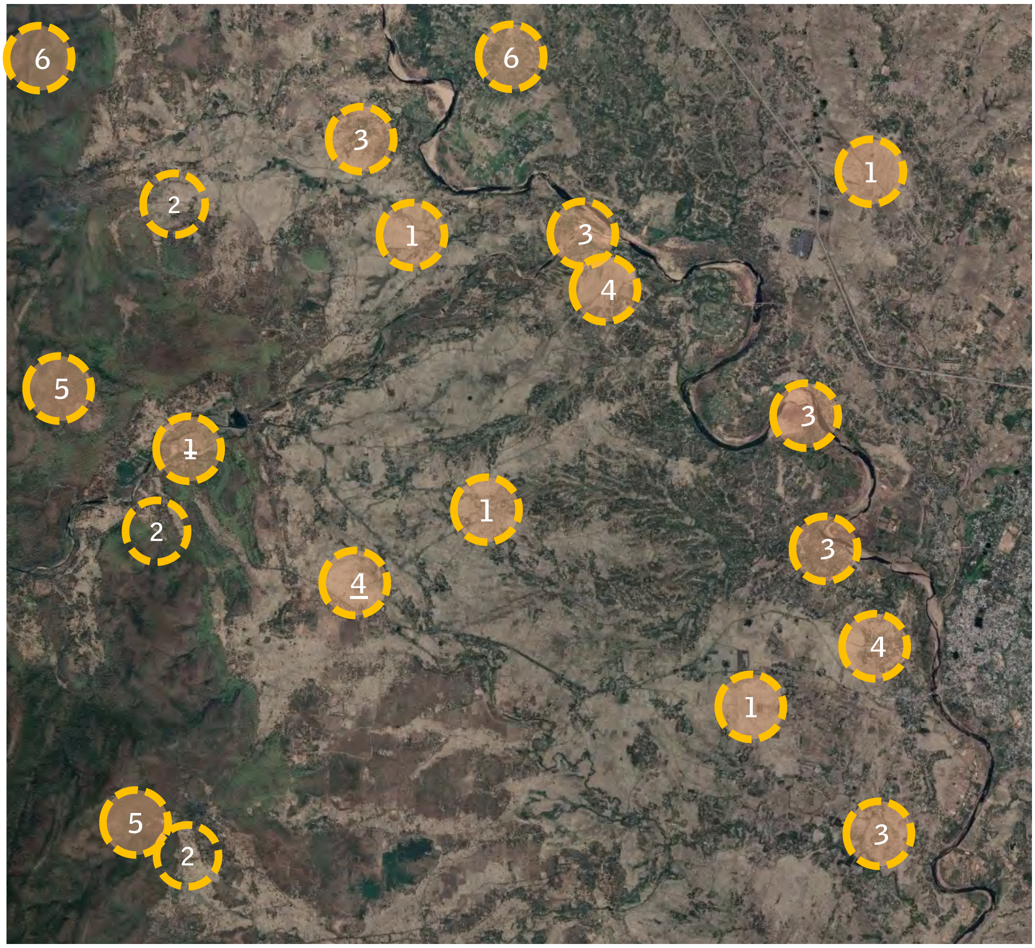
Forest in the area

Typical housing cluster in villages

Farmlands used for rice cultivation

The area is located between a mountain range and the Burhabalang River. It is very fertile and is primarily used for agriculture. Villages in the highlands closer to Similipal mountain range such as Lulung and Kakarpani have an abundance of natural stone as well as local vegetation such as Bamboo, Neem, Sal and other varieties of wood. The region lies in Seismic Zone II, which is of low damage risk as per Odisha State Disaster Management Authority. However, the region experiences flooding once in one or two years along the riverine edges.

RESOURCE MAPPING



1. Rice straw as an agricultural by-product

The straw which is a by-product from the cultivated rice is processed, dried in the sun, and used as roofing material.

2. Natural stone

The highlands close to the Similipal reserve forest are rich in natural stones. These stones are found at a depth of 0–90 cm from the top layer of the ground. They are excavated, cut and chiselled to be made into pieces that measure 45 cm in width and 3–5 cm in thickness. These stones are used to make walls with mud mortar as binding material.

3. Soil

The region is a flood plain, rich in its soil variety due to alluvial deposits. The soil from agricultural land and riverbanks is primarily used for making mud mortar. Coarse soil is mixed with fine clayey soil and water to make the mixture for cob-based walls.

4. Laterite stone

Laterite stone is used for the construction of plinths and columns. Mining is banned in the region but the use of laterite blocks persists.

5. Neem, Sal and other local varieties of wood

Wood from Neem, Sal and other trees is used for making structural members such as columns, beams and under structures for the roof.

6. Bamboo

Different varieties of local bamboo of varying thicknesses are cultivated and used for different purposes like roof structures, wattle in wall construction, under structure of a thatch roof, etc.

BUILDING TECHNIQUE:
BAMBOO THATCH ROOFING

Step 1

The central ridge member is placed across the length of the room, with the help of temporary supports.

Step 2

Hip rafters are placed at the corners and the temporary support for the ridge member is removed to create the understructure for the roof.

Step 3

Bamboo stems of different sizes are used for different members. Bamboo stems of roughly 10 cm thickness are cut into two splits and used as rafters in the roofing framework, and laid between the ridge member and the wall. The purlins are placed along the length of the wall, for supporting the thatch.

Step 4

Thinner stems of roughly 2–3 cm are used to create a mesh layer for extra support over the rafters for the thatch bundles to be laid on.

Step 5

One worker positions himself/herself on the roof, placing and aligning the thatches on the purlins, while another worker throws up the thatched panels to the worker above.

One worker on the ground passes the thatch bundles to another worker on top

The thatch bundles are orderly placed over the layer below, to avoid gaps in the roof

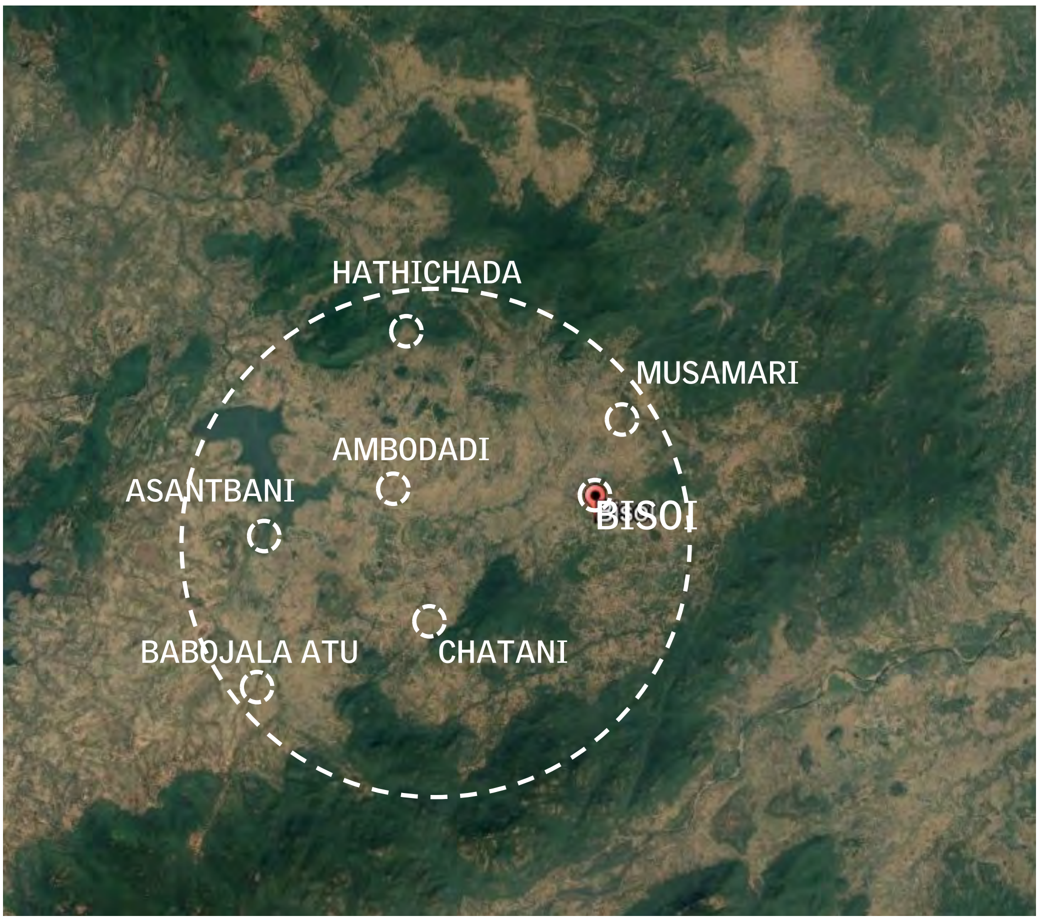
Step 6

The thatches are placed, layer by layer, starting from the bottom purlins, towards the ridge member. They are held in place using split bamboo purlins laid on top of a layer of thatch and are tied to the rafters.

BISOI

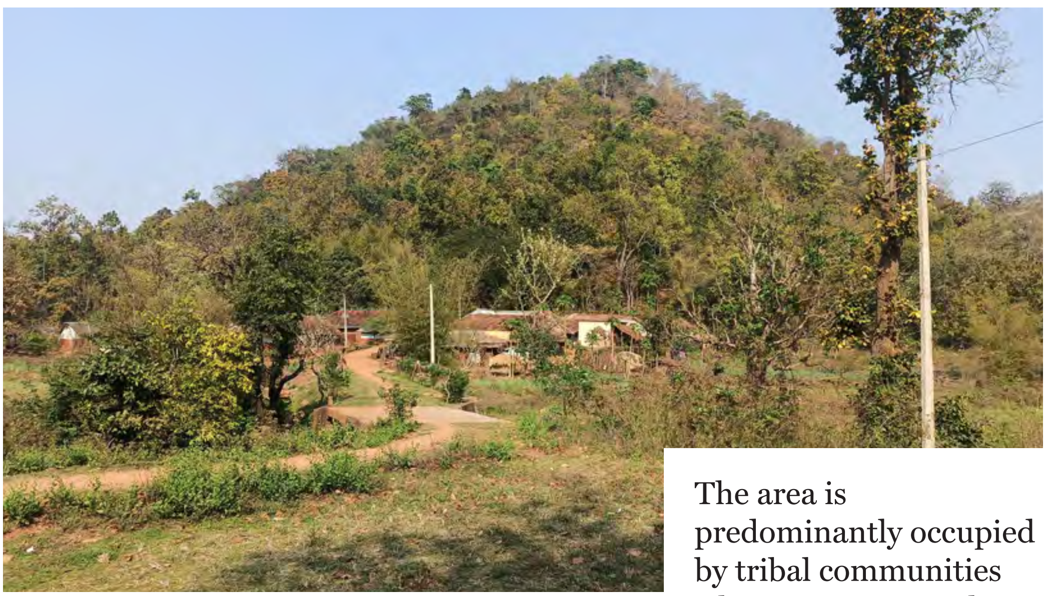
Location: 90 km from Kolkata
Geomorphological classification: Pediment - Pediplain complex
Climate: Warm and humid

C o n t e x t | G e o g r a p h y | V e g e t a t i o n



Bisoi is located in the foothills between the mountainous highlands of Gorumahisani mountain range and the northern part of Similipal mountain range (which is also a national park). There are multiple settlement clusters in the region and each one has about 50–80 houses.

Farmlands in the foothills of the highlands



Forests and mountains in the region with scattered housing on it

The area is predominantly occupied by tribal communities who practice agriculture and collect forest products such as timber and leaves to sell in the local markets.


Bamboo groves in the area


Local vegetation such as Sal and Paisal

RESOURCE MAPPING

1. Rice straw from agriculture

Agricultural waste from locally cultivated rice varieties is used to make thatches for the roof. These thatches require yearly maintenance as they undergo wear and tear from rains and wind.

2. Fine and coarse soil

The residents use the soil either from the building site and/or nearby agricultural land. Locally sourced fine and coarse soil is mixed to make mud daub which is used in making walls.

3. Random rubble/stone

Random rubble and other natural stones can be seen along the highlands as well as along the water bodies in the region. They are used mostly for making plinths.

4. Natural timber

Salwood and *Dharka* are the most used varieties of timber and are sourced from nearby forests. They're used for fencing, wood wattle in walls, lintels, columns, beams and roof frameworks.

TRADITIONAL BUILDING MATERIALS AND TECHNOLOGIES

I. Walls

TYPE 1: Wattle and daub

Local bamboo is used as the wattle while the soil is used as daub. The walls are roughly 15 cm in thickness. This type of construction requires periodic maintenance, as the mud daub cracks in the summer heat, and gets dislodged by floods. Another variation of the same, with local wood used in the place of wattle, can be found in the region. This technology and its variations were observed in both **Bisoi** and **Baripada**.

TYPE 2: Flat stone masonry

Flat stones of irregular sizes are used to build walls and, in some cases, made into columns. The wall is eventually plastered with mud. It is mostly found in the highland regions of **Baripada** and a few buildings made by the technology have lasted more than 75 years.

TYPE 3: Cob walls

Clayey soil and coarse soil are mixed with cow dung and water to make a homogenous mixture. This mixture is made into lumps and placed layer by layer to make walls of around 30–45 cm thickness. In some villages of Baripada, laterite blocks and large stones are cut out in longer pieces and used for making support structures such as columns.

II SCREENS

TYPE 1: Woven mats from thatch

Woven mats made from local grass and rice thatches are used as screens. They provide a certain level of protection primarily from winds, rains and direct solar radiation. They also act as envelopes for extended spaces such as verandas and storerooms.

III. ROOFS

TYPE 1: Thatch roof

Local grass and straw from rice cultivation are processed and used as roofing thatch. These thatches are prone to wear and tear due to climatic conditions and hence require periodic maintenance. This is found both in **Bisoi** and **Baripada**, especially in the areas with higher presence of tribal population.

TYPE 2: Flat clay tiles

Flat clay tiles are sourced from local markets or nearby villages. The purlins which hold the tiles are placed at a gap of one tile length. The tiles are placed one on top of the other in such a way that they overlap and lock on to one other. These tiles have been observed both in **Bisoi** and **Baripada**.

TYPE 3: Curved clay tiles

Curved clay tiles, locally known as Khoppar, are placed one on top of another. They are made from mixing clay with water and burning the mixture in the kiln. The purlins are placed at a gap of each tile length. These type of roof tiles are predominantly found in **Bisoi.**

TRANSITION: RENOVATIONS AND NEW CONSTRUCTION

The villages in closer vicinity to bigger towns such as Baripada have had a faster rate of transition to conventional materials than the ones relatively isolated on hills. Bricks, concrete columns and beam systems have replaced traditional technologies. In some cases, mud mortar has been used in the place of cement mortar for red brick wall construction.

Red bricks and mud mortar

GI sheets

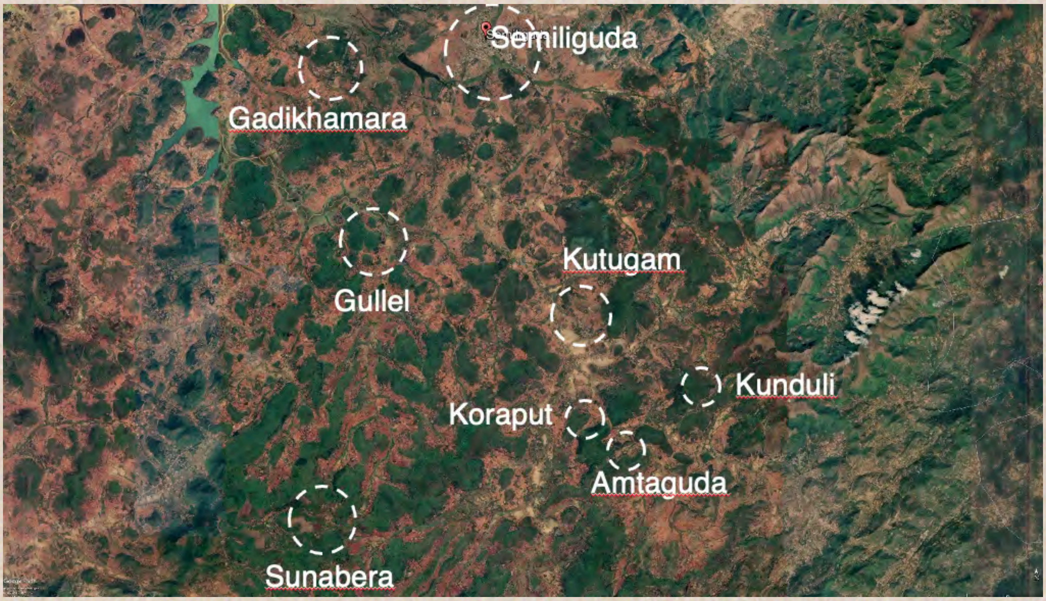
Cement plaster over brick walls

05

SEMILIGUDA

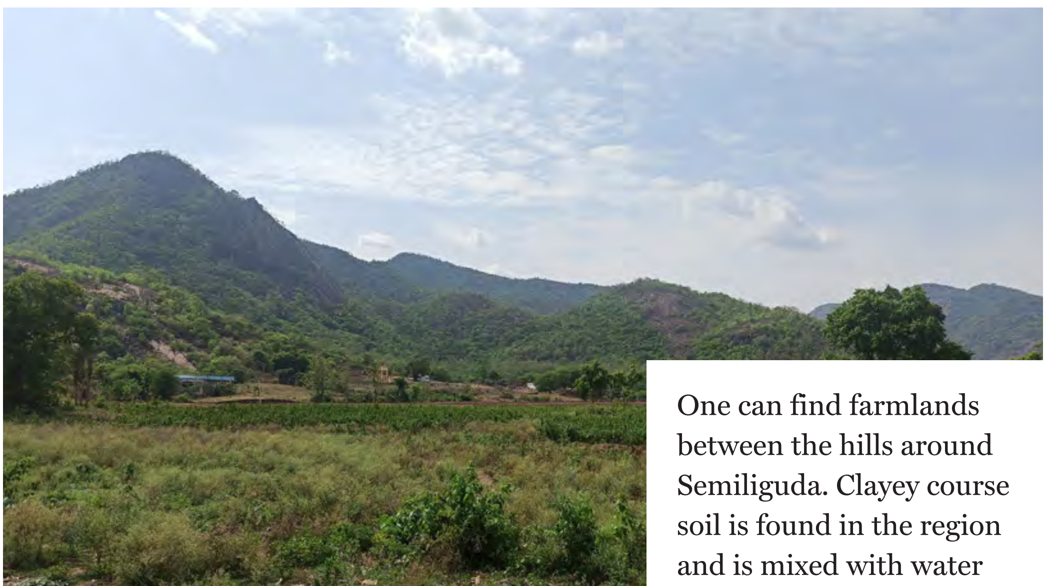
Location: 483 km from Bhubaneswar
Geomorphological classification: Low dissected hills and valleys
Climate: Warm and humid

Context | Geography | Vegetation



Semiliguda, which was once a series of small tribal villages within dense forests, became urbanized after the setting up of Hindustan Aeronautics Limited in 1968 and National Aluminum Company in 1981. It lies in the central plateau region of Odisha and is surrounded by a series of small hills. Most of the native population belongs to tribal communities and is involved in agriculture and daily labour jobs.

Agricultural fields in the region



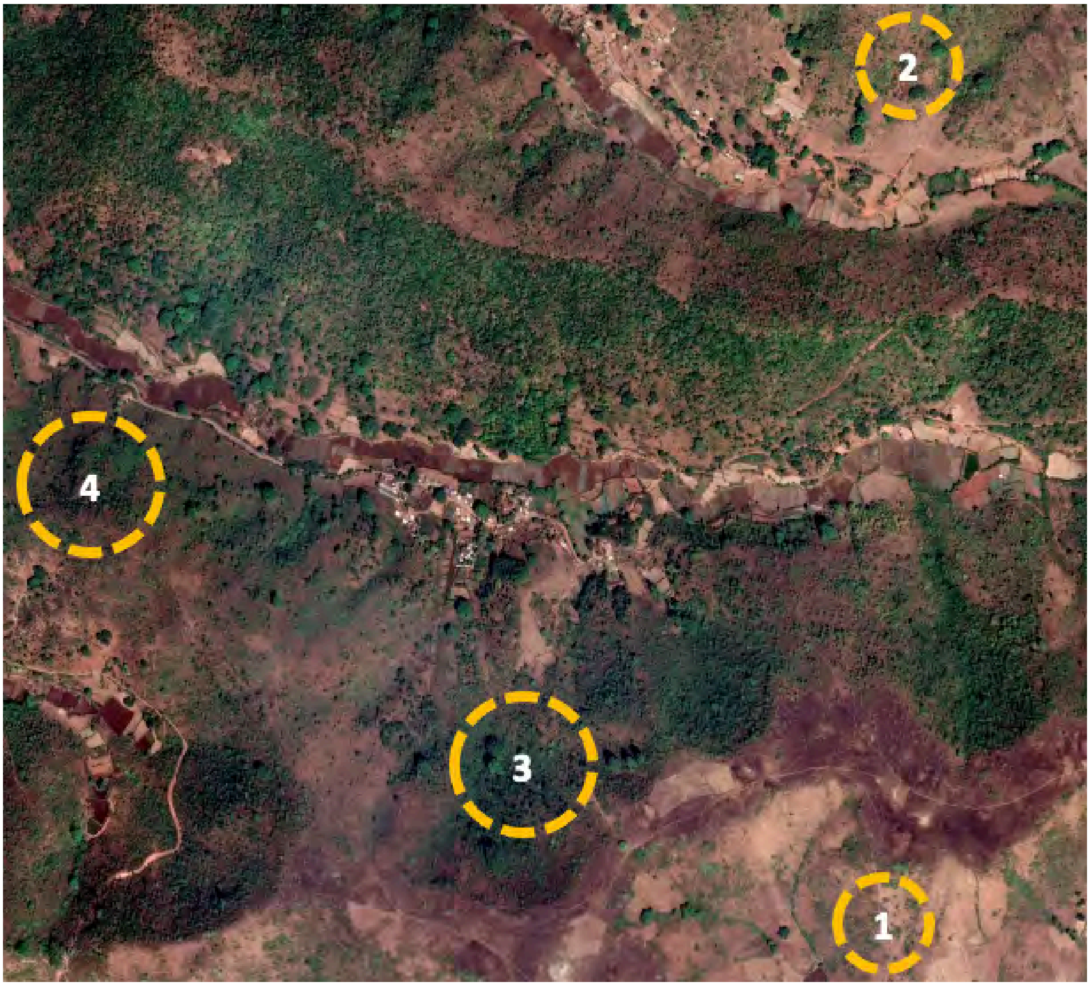
Natural vegetation

One can find farmlands between the hills around Semiliguda. Clayey course soil is found in the region and is mixed with water to build walls for houses. Straw thatch, natural stones and locally found vegetation are used in construction of traditional housing.

Farmlands around the villages in the region

Typical housing cluster in the region

RESOURCE MAPPING



1. Straw

Straw, which is a by-product from cultivated rice, is dried and processed before being used as thatch for roofing.

2. Natural stone

The highlands in the region are rich in natural stones. They are abundantly found on the surface or within a meter of excavation.

3. Sal, palm, mango and other local varieties of wood

Wood from Sal, palm, mango and other local trees is sourced from nearby lands and forests. They're used for lintels, columns, beams and roofing frameworks.

4. Bamboo

Bamboo is cultivated in small pockets of land near the villages and in the forests and is primarily used for making roof structures.

TRADITIONAL BUILDING MATERIALS AND TECHNOLOGIES

I. Walls

TYPE 1: Cob wall

Clayey and coarse soil are mixed with water to make cob-based walls of roughly 30 to 45 cm thickness. They are then smoothened and plastered with mud. Periodic maintenance has to be carried out as it gets damaged with torrential rains and develops cracks in the summer.

TYPE 2: Random rubble stone masonry with mud mortar

Random rubble with mud mortar is used to build walls and, in some cases, to make columns. Mud daub is used to plaster these. This type of construction lasts for more than 75 years and provides thermal comfort in all weather conditions.

II. ROOFS

TYPE 1: Flat clay tiles

Flat clay tiles are locally sourced from nearby villages. They are made from clayey soil mixed with water and burnt in kilns. The tiles are also made in such a way that they can be laid on the purlins to overlap one another. The purlins are placed at a gap of each tile length.

TYPE 2: Straw thatched roof

Local agricultural by-products such as straw from rice cultivation are processed and prepared for roofing. The thatch work requires periodic maintenance, due to wear and tear.

TRANSITION: RENOVATIONS AND NEW CONSTRUCTION

It was observed that the traditional walling technologies such as cob-based walls have been largely replaced with conventional brick-mortar construction. Construction of roofs has also shifted from thatch and flat tiles to asbestos and concrete. In multiple cases, mud mortar is used instead of cement-based mortar to save costs.


Red bricks and mud mortar


Brick walls
Asbestos


Cement plaster over brick wall

TRIBAL HOUSING IN ODISHA

According to Census 2011, Odisha has the third highest percentage of tribal population in India. Tribes constitute about 22.85 per cent of the state's population. That is nearly 96 lakh people. There are about 62 tribal communities in the state, according to the Scheduled Caste and Scheduled Tribe Research and Training Institute (SCSTRTI), which have a distinct culture and way of living. This includes the way they construct their houses. SCSTRTI has developed life-size houses of some of these tribes at the Odisha State Tribal Museum located in Bhubaneswar. These houses serve the purpose of demonstrating the techniques and the way of living of the tribes. CSE has documented these houses to understand the material usage and construction techniques involved.

1. Juang Hut (Injza) and Dormitory (Majang)

These types of houses are predominantly found in Keonjhar and Dhenkanal districts of Odisha. The thatching for the roof is done with a type of grass available in the nearby forests and soil is sourced from local agricultural fields and nearby land. Extract of mango bark, mixed with cow dung, is used as a plaster over the walls, which acts as an anti-termite agent. Bamboo and different varieties of wood are used for making rafters for the roof.

Juang Hut (Injza) & Dormitory (Majang) [in the top right]; Wooden column [top left]; Verandah [bottom left]; rice smasher [bottom right]

PHOTOGRAPHS BY: HARIKRISHNAN C U

2. Santal Hut (Olah)

The Santal tribe is primarily a community of farmers and herders. They are located in the Mayurbhanj, Balasore and Keonjhar districts. The buildings are made from locally available materials such as soil and rice straw which is an agricultural by-product. The same straw is also used for making thatched roofs. Handmade tiles are made from clayey soil in local villages. Multicoloured wall paintings and drawings are done on the re-plastered walls, as part of the annual festivities.

Santal Hut, exterior view [top]; Interior view [bottom left]; cow shed [bottom right]

3. Gadaba Hut (Chhendi Dien)

These houses are predominantly found in Keonjhar, Jeypore and Dhenkanal districts of Odisha. A central post made of Sal wood supports the entire roofing structure. Flooring and kitchen elements such as earthen stoves and plinths are moulded out of locally sourced soil and shaped in circular layers. The circular nature of the walls helps in making the buildings more resistant to earthquakes. The space within the house is divided from the central pole to wall edges for rooms.

Gadaba Hut exterior (left); Interior (center); and thatched roof (right)

Kandha Hut, exterior view [top]; Interior view [bottom]

4. Kandha Hut (Idu)

These are occupied by the Kandha, Kutia and Dongria tribes, and are mainly located in the districts of Rayagada, Kandhamal and Koraput. The walls, columns, windows, doors and roofing frameworks are built with locally available wood. The walls are made by stacking wooden panels next to each other and sealing the edges with a soil mixture plaster. Flooring is done with a mixture of mud and cow dung.

5. Gond Hut (Loth)

These huts made by the Gond people are located in Nabarangpur, Sundargarh, Sambalpur, Bolangir, Keonjhar and parts of Kalahandi districts. They use locally available resources like loamy soil, bricks and wood to make tiles and intermediate floors, which are used as storage and sleeping spaces. The housing clusters are built in a linear pattern.

Gond hut exterior view [in the top and bottom right]; Verandah [top right]; Intermediate floor [bottom right]

Chuktia Bhunjia [top]; Interior views [in the middle and bottom left]; and attic [bottom right].

6. Chuktia Bhunjia Hut

They are primarily located in the Sunabada and Naupada districts of Odisha. They are built with locally available materials such as bamboo, mud, wild leaves and straw. They build a separate shelter for their livestock such as cows and goats. These houses are usually three-quarters bigger than the exhibit model. The doors, windows and attic spaces are made from bamboo. The attic is used to store grains and other utensils. They build their 'Lal Bungalow', which is a kitchen space, outside their homes and consider it sacred and exclusive to the family.

7. Saora Hut

These types of huts are found in Gajapti and Rayagada districts of Odisha. They are occupied by a primitive tribe called Lanjia Saora. These tribes are primarily agrarian in nature and build livestock shelters within their verandas. They practice terraced and swidden cultivation. Detailed wall paintings (idital) are also done both in the interior and the exterior of the walls.

Saora Hut, exterior view [top left]; interior view [top and bottom middle]; livestock shelter in veranda [right and bottom left]

Chapter 5: Fusion technologies

The rural communities of Odisha and West Bengal have evolved over the years to adapt to adversities such as cyclones and earthquakes as well as the changing climate. This evolution has influenced the use of traditional technologies and brought about a new wave of 'fusion' technologies.

The location and geography of Odisha and West Bengal make them vulnerable to cyclones and earthquakes. For instance, Cyclone Amphan hit both the states in May 2020 and affected more than 13 million people with many of them losing houses, crops and lands. The hilly region of West Bengal also witnesses earthquakes and landslides. This requirement has led the people to use material that makes for strong houses which can withstand such onslaughts of nature.

For instance, due to frequent flooding, people in Sundarbans and Belari have combined wattle and daub technology with precast posts or brick columns. In the coastal plains of Odisha, people place fishing nets over thatch roofs to prevent the roof from blowing away in case of high-speed winds.

Precast concrete posts being used in houses in Sunderbans region

Brick columns used in tandem with wattle-daub walls in Uluberia

PHOTOGRAPHS BY SUGEET GROVER

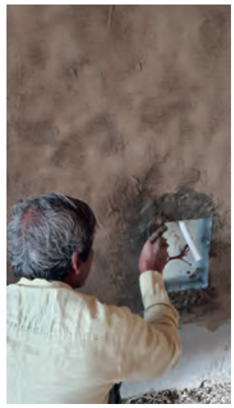
Such innovations are mostly self-engineered and there is a tremendous need as well as opportunity to guide these to maximize the benefits of fusion technologies. A few local architects and practitioners have come up with their own fusion technologies by marrying traditional and modern technologies to reap the advantages of the two approaches. This includes largely combining the durability and stability of modern technologies with better thermal comfort and more employment opportunities linked with the traditional technologies. For instance, use of technologies like cob, adobe blocks, wattle and daub as infill materials in a framed structure. This makes the outer skin of the building sturdy enough to withstand extreme weather events whereas the infill walls, intermediate floors, etc. still employ local materials ultimately making the overall construction cheaper. These works are also an attempt by these architects towards preserving local technologies, skilling local labour and reducing material intensity.

This section comprises some of the fusion techniques observed in Odisha and West Bengal.

Classroom prototype in 'Free residential school' by Laurent Fournier, Kolkata

Traditional technologies used	Conventional technologies used
Wattle and daub walls using bamboo, mud	Burnt brick
Mud and Gobar flooring	Reinforced cement concrete
Mud and lime plaster	Glass

The building utilizes a combination of burnt brick, concrete columns, walls made of wattle and daub and mud flooring. The concrete columns provide structural stability while the wattle and daub walls act as fillers between them. The walls incorporate modern services such as electric fixtures within them and have good insulation and sound absorbing properties which are needed in a classroom.



PHOTOGRAPHS BY SUGEET GROVER

SOURCE: LAURENT FOURNIER

SOURCE: LAURENT FOURNIER

SOURCE: LAURENT FOURNIER

Unnamed house by Bidyut Roy, Bolpur

Traditional technologies used	Conventional technologies used
Adobe blocks	Brick
Elephant grass mats	Reinforced cement concrete columns
Curved terracotta tiles	RCC beams
Wooden beams for flooring	

The structure utilizes concrete columns and beams while the infill walls utilize adobe bricks that have been made onsite. The manufacturing of adobe bricks utilizes local labour and material, saves transportation cost, is significantly less energy intensive than red bricks and provides good thermal mass that in turn is good for occupants' thermal comfort. A few courses of red brick are used at the base of the wall as this area is more prone to water splashes. The walls are finished with mud plaster.

PHOTOGRAPHS BY SUGEET GROVER

The under structure of floor uses timber from Tal wood which is then topped with wooden flooring, thus avoiding RCC slabs. The building uses triangular window frames that avoid RCC lintels, this technique is derived from triangular windows present in villages of Bolpur region.

PHOTOGRAPH BY SUGEET GROVER

The Mud House, Bolpur

Traditional technologies used	Conventional technologies used
Adobe blocks with lime	RCC filler slabs
Elephant grass mats	Concrete columns
Curved terracotta tiles	Concrete beams
Wood flooring and wooden columns	

PHOTOGRAPHS BY SUGEET GROVER

This hospitality building, located in Bolpur, West Bengal is another example of creatively used hybrid technology. The ground and first floor of the structure have RCC columns and beams while the top-most floor is made of a completely soil-based structure with wooden columns. The structure uses sun dried adobe blocks that contain soil, water, lime (5%), human hair (sourced from local barbers) and chemicals to keep rodents and termites away. These bricks are used for external and internal walls and mud plaster is used in finishing of the walls.

RCC slabs are only used in the bathrooms and corridors and use the filler slab technique that saves quantity of concrete while also making the structure lighter.

The building has been standing for seven years and its maintenance requirement has reduced every consequent year.

Housing prototypes by a consortium of architects, designers, students and engineers led by Sangita Kapoor's 'Blue Planet'

Traditional technologies used	Conventional technologies used
Terracota tiles	Precast concrete posts
Thatch roof	Hydraform blocks
Bamboo walls	Burnt bricks
Bamboo flooring	
Wattle and Daub walls	
Mud-Lime plaster	

Housing prototypes in Purb Sridharpur

PHOTOGRAPHS BY SUGEET GROVER

Three demonstration houses have been created in the village of Purb Shridharpur, which lies in the Sundarbans delta region of West Bengal. The region is prone to frequent floods and cyclones, which have increased in frequency in the last few years. The projects consist of three houses built with hybrid building elements and act as a repository of various technologies that can be applied in the region. The houses are made mainly using local materials and are designed to be more resilient to frequent flooding and cyclones.

The first house uses precast concrete posts pegged into the ground. This provides the structure with stability and braces the bamboo structure to the ground. The rest of the structure majorly uses bamboo walls with bamboo-mud flooring.

The second house is load bearing and uses Hydroform blocks which were sourced from around 80 km away from the village. The under structure of the roof utilizes bamboo and the final roof is made from locally sourced reused terracotta flat tiles. High winds damage flat terracotta tiles and that has been a major reason why people have shifted away from them. To solve this problem, bricks have been placed over these tiles as ridges to keep the tiles from getting damaged and flying off.

Housing prototypes in Purb Sridharpur

The third house again utilizes precast RCC posts placed in a tripod form that make the structure more earthquake resilient. The intermediate floor uses a shallow dome technology which cuts down the need for steel and concrete in the structure. The walls are made from wattle and daub technology with mud-lime plaster.

Thatch panels

PHOTOGRAPHS BY SUGEET GROVER

The thatch roof requires a special mention in the project. It utilizes local materials such as rice thatch for the covering and bamboo as the under structure. However, the technique of creating this roof has been modified slightly from the traditional one. In this modified construction technique, the panels are pre-made on the ground, use denser thatch and additional knots are added to the process of tying the thatch with the bamboo runners. This increases the life of the thatch roof, reduces maintenance and makes the roof more resilient to winds and heavy rains.

Local women-force engaged in making thatch panels on ground

PHOTOGRAPHS BY SUGEET GROVER

The local labour force was trained in the making of these panels, ultimately building capacity in a new technique for the region while still utilizing locally available materials. The traditional way of building required labour to climb up the roof under structure to place the thatch, this discouraged the women labour force from participating in this process. However, as the process of making these thatch panels is done on the ground, women are now able to participate in the process and this technique has now been adopted throughout the region. This innovation in thatch panel production has been inspired by a technique used in Indonesia and is a perfect example of how experimentation and cross-learning can bring new life into usage of traditional materials while generating more livelihood opportunities.

Guest house by Udit Mittal, Qx Design studio, Purb Shridharpur, West Bengal

Traditional technologies used	Conventional technologies used
Thatch roof	Ferrocement
Bamboo walls	Precast RCC posts
	RCC beams

The guest house is another example of hybridization using local building materials. It was constructed using local labour force and materials from nearby areas. Precast concrete posts were used to make the foundation, and ferrocement was used in constructing the staircase.

Making of foundations with precast concrete poles

Chicken mesh layer, used for making the reinforcement for staircases.

The structure above ground has been made using bamboo poles, fasteners, nylon threads, local ropes and bendable wires. The under structure of the roof is made from bamboo over which thatch is placed. The floor of the structures is made from shallow dome technology that drastically reduces the amount of steel required when compared to RCC slabs.

Roof made from bamboo and rice thatch

Shallow dome construction acts as a substitute to RCC slab

Thatch roof

Guest house with thatch roof

SOURCE: SAURAV JANA, QX DESIGN

Prakriti Hunar Lokvidya – PAHAL Volume 2

The government of India launched *PAHAL Volume 2: A compendium of Rural Housing Typologies* to guide the implementors of PMAY-G to make informed decisions about size, typology, technology, etc. UNDP, IIT Delhi and CSIR-CBRI were instrumental in making this document. This compendium involves 18 states and divides them into different zones based on their local geo-climatic conditions and provides relevant housing designs.

The solutions suggested in the compendium combine conventional materials such as brick and concrete with traditional materials such as timber, bamboo and mud; they also include neo-sustainable technologies such as rat-trap bond, filler slab and ferrocement shells. The aim is to introduce modern techniques—like reinforcement in masonry, better joints, treatment of bamboo and timber, and lime stabilization of earthen technologies—into traditional housing construction to improve their risk-mitigating features. The designs amalgamate the strengths of conventional construction materials (cement and brick) with traditional materials (timber, bamboo, mud).

The dwelling designs proposed offer a wide range of size options ranging from 25 sqm to over 65 sqm in some cases and offers solutions for foundations, plinth, walls, wall finishes, roof structure, roof cover, floor etc. The Ministry of Rural Development proposes to build demonstration structures using these hybrid technologies in coordination with state governments. However, states are yet to pick up these designs for implementation.

Chapter 6: Way forward

Even though official documentation of traditional building materials and techniques has begun, more focussed policy framing is needed to promote, support and fund hybrid and fusion technologies in the self-built housing sector, especially in peri-urban and rural areas. This will require deliberate strategies.

Develop a comprehensive compendium and knowledge repository of traditional and fusion construction technologies to inform self-built housing programmes: Through its compendium of indigenous technologies, BMTPC has started recognizing traditional technologies. This needs to be taken forward for more comprehensive documentation. State governments also need to document more technologies for the self-built housing segment while taking into account the local nuances based on material availability. There is immense diversity in traditional materials and building techniques nation-wide that needs mapping as well as support from the technology demonstration centres and research conducted by institutions.

Provide guidelines, norms, and certify traditional and fusion technologies: The biggest roadblock for mainstreaming of traditional and fusion technologies is the lack of testing and certification of these technologies. While scientific literature has proven the thermal comfort and disaster resilience benefits of most of these technologies, absence of standards and tested evidences has prevented their uptake in the market. These technologies need to be evaluated for their performance on thermal comfort and disaster resilience. Based on this technical evaluation, traditional and fusion technologies and the skills related to them need to be certified. Some initiatives like those pioneered by organizations like Hunnarshala in Gujarat have already begun to generate more data and evidence on these technologies. This needs to be taken forward at scale.

Mobilize informal knowledge and skills to strengthen the sector: Knowledge and skill of traditional technologies is largely transferred informally. It is either passed on from one generation to another or through informal instruction by a mason. This network of masons has great potential for demonstration-based learning and skilling. A step-by-step guidebook needs to be created to capture the skill. This must be linked with the knowledge repository. For dissemination and further skilling, state governments need to create local institutional frameworks that facilitate networking between trainees and trainers and roll out under skilling and livelihood programmes. Certification of traditional technologies and skills can catalyse significant changes.

Develop prototypes at innovation and demonstration centres: There are many technology demonstration centres in India. This investigation captured 12 such centres. There is potential to demonstrate more traditional and fusion technologies at these centres. All state governments must develop prototypes based on the documented technologies for demonstration-based learning. Funding strategy and policies need to support hybrid approaches and local technologies to promote their use in contemporary modern self-built houses in both rural and urban areas. Several projects or architects and practitioners have already demonstrated how the combination of traditional and new technologies can work efficiently while improving thermal comfort, durability and cost effectiveness. Innovative use of conventional materials like burnt-clay bricks, cement, concrete, etc. along with the new material can provide a range of solutions for sustainability. These need to be demonstrated and promoted.

Need zoning for climate-appropriate response in promotion of construction technologies: Different parts of any state face varied exposure to disasters and climate vulnerability. For instance, Odisha has a coastline that is frequented by high-speed winds and cyclones while it also has hilly forest areas with different kinds of vulnerability. Similarly, West Bengal has a highly eco-sensitive Sundarbans region as well as the hill districts of Darjeeling and Kalimpong. To address this variability, states need to zone their areas and guide choices of construction technology and materials accordingly. Vulnerability mapping will be crucial in order to provide an appropriate response.

Update schedule of rates for formal adoption of these materials: The states need to include traditional and hybrid technologies and the materials used under them in their schedule of rates for procurement. This will push uptake and mainstream these technologies in the construction sector.

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Self-built housing is of critical importance in India as it is the principal source of housing supply in both urban and rural areas. Yet, this sub-sector of housing is often ignored and overlooked.

Traditionally, this sector primarily utilizes construction techniques that have evolved over the course of hundreds of years in response to the local climatic conditions and availability of materials. This has resulted in techniques, material compositions and forms that are most resilient, adaptable and easily repairable within the local context. However, this local knowledge is now ignored in favour of more mass-produced industry-based construction technologies.

That needs to change in this climate challenged world. CSE has taken this initiative to create this compendium solely focused on traditional construction material, technologies and skills in different climatic zones. This initiative spreads across 11 states including a deep dive assessment of technologies available in Odisha and West Bengal—the states which are most vulnerable to extreme weather events.

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