The settlement of Birabalabhadrapur, 8 km north of Puri, is a settlement built in the 1650s comprising of around 120 households is a good example of climate responsive architecture that emphasizes the use of local materials. The village is formed along an east-west running tree lined path connecting two temples. Either side of the straight road, two parallel rows of one-storey courtyard houses face one another, about 25 metres apart. Their frontyards are surrounded by clusters of tall coconut palms.

**MATERIAL USAGE & CONSTRUCTION SYSTEM**

**TYPOLOGY**
Courtyard houses attached to each other with courtyards in each.

**STRUCTURE**
Timber and cured bamboo framing encased in mud. Bamboo is cured in water for two weeks, in the sun for two weeks and then smoked indoors as protection against insects. Rough-hewn laterite posts are sometimes used.

**ROOFING SYSTEM**
Sloping roofs with wooden ridge members and purlins run between cross walls covered with a mat of bamboo and thatch is of rice straw. Ceilings are unfinished bamboo. Double roof construction is used in storage areas with a mud roof some 300-400 mm below the thatched roof. (U-value = 0.23 W/m²K).

**WALLING SYSTEM**
External walls are generally 200-300 mm thick, the mud held in place by loose bamboo mesh that is densely woven using a wattle and daub technique (U-value = 2W/m²K). The wall framing and the infill mesh can be entirely of bamboo with timber for the main posts, beams and rafters. Division walls standing alone are thatched. Over time, mud walls have begun to give way to brickwork or laterite blockwork.

**DOORS/WINDOWS**
Doorways and window grills are wooden. The windows are often richly carved.

**FLOORS**
All roofed parts of the house are raised above the ground, the open-to-sky part of the courtyard remaining at ground level. Laterite bricks are used instead of mud in a 600 mm high plinth. The floor inside the house is of swept earth. In some places there is suspended floor, with a pit underneath for even cooler storage. The swept earth of the floor modulates into small fire pits, with an air hole in front, and is moulded to hold a pot.

**SEMI-OUTDOOR SPACES**
A narrow open to sky courtyard in each house with a large covered space around it that acts as the living room. Generally one side of the courtyard is covered by a roof, the wall on the other side is sheltered by the overhang of the neighbour’s roof, while at its foot, the neighbour’s platform projects a plinth to protect base of the wall, as well as forming a useful seating area and shelf. The front of the houses form a continuous row, raised on a high plinth, projecting from the front of the house to from a shaded sitting place beneath thatched eaves.

**LCCR FEATURES**

- **Siting and orientation:**
  - Protected from wind, run and sun from the east and west by adjacent houses and tree clusters.
  - External openings to the north and south.
  - The deep narrow courtyard allows sun in north and south sun.
  - East and west sun gets shaded well by the eaves of nearby roofs.

- **Thermal strategy:**
  - Terraced typology and overhanging roofs provides shade.
  - Courtyard allows rise of hot air through stack effect and acts as a buffer space for rooms.
  - The high roof with the bamboo ceiling further cools down the interior because of the air gap in between (especially in storage areas).

- **Ventilation strategy:**
  - Cross ventilation through the courtyard and the double roof.

- **Daylighting:**
  - Speciﬁc housing maximum luminance level (i.e the cooking and living spaces) receive much diffused light through the courtyard or directly from the open sky.

- **Rain sheltering:**
  - Sloping roofs provide a clear run off for all rainfall.
  - A 600mm high plinth provides protection from damp and termites.
  - The storage spaces for food are the most interior in the house plan, getting maximum protection from the rain.
During the cyclone of 1994 the house belonging to Abdul Motaleb became a shelter for hundreds of women and children of the Dangorpara area. The local people felt confident that the house would withstand the cyclone as it had withstood previous ones. This case study shows how indigenous housing can be modified to withstand harsh climatic conditions.

**MATERIAL USAGE & CONSTRUCTION SYSTEM**

<table>
<thead>
<tr>
<th>TYPOLOGY</th>
<th>Detached individual house</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROOFING SYSTEM</td>
<td>A hip roof. The structure consists of wooden joists and purlins with a roofing material of tin sheets supported by wooden pillars. (U-value: 0.9 W/m²K)</td>
</tr>
<tr>
<td>WALLING SYSTEM</td>
<td>The internal walls are mostly bamboo mat and wooden plank. The external walls are brick and plaster. (U-value: 0.31 W/m²K)</td>
</tr>
<tr>
<td>FLOOR</td>
<td>Tinted Concrete Floor</td>
</tr>
<tr>
<td>DOORS/WINDOWS</td>
<td>Wooden planks with wooden frames</td>
</tr>
<tr>
<td>BUFFER SPACES</td>
<td>The traditional houses in these areas consist of a pashchati - a verandah type space enclosed with a parapet/wall</td>
</tr>
</tbody>
</table>

**FUNCTIONAL ZONES**

- Kitchen and eating
- Living and Sleeping
- Sleeping
- Pashchati (open)

**LCCR FEATURES**

- Siting and orientation: - Surrounded by trees and other houses that act as wind breaks. - The pashchati of the house is mostly north and south facing.
- Thermal strategy: - The pashchati acts as a thermal buffer with the exterior for the inner living spaces. Also, the thermal functionality of this space varies seasonally. - The solar gain in the summer seasons is minimal due to effective shading provided by the eaves of the roof while in winter, there is low sun received into the pashchati.
- Ventilation strategy: - Good cross-ventilation through the house out into the pashchatis. - Exhaust from cooking area does not reach living areas.
- Daylighting: - The spaces which need maximum luminance levels (i.e. the kitchen and the living room), are either on the exterior or gain much diffused light through the pashchatis.
- Occupant Adaptation: - The pashchatis are used during the winter season when sunlight percolates into the building envelope well while during the summer, the interior cooler spaces of the house are occupied.
- Cyclone resistance: - To reduce the high pressure on the internal surfaces of the wall these houses are built with only one opening on the pashchati. - The pashchati wall works as a barrier and reduces water penetration into the house during high wind accompanied by rain. - The roof shape hence invariably is hip roof, and the pashchati roof is separated from the hip roof, and because of this separation, roof of the pashchati usually suffers wind damage without affecting the roof of the house. - High level of competence in joinery details further increases cyclone resistance. These connections to resist high velocity winds include - the use of steel angles and bolted connections to fix the different members of the roof structure to the vertical wooden post, extra support to the ridge of roof, and extra tie for extended roof overhang.

Sections of courtyard houses showing various passive strategies employed.
POST-CYCLONE RECONSTRUCTION WORK
ASHRAYA CORE HOUSE PROGRAM, ORISSA

The Ashraya Core House Construction Program, in partnership with CARE India designed to respond to the reconstruction needs after the Super Cyclone in October 1999. It addresses the immediate shelter needs of about 1400 families by providing a fast response to construct Core Shelter. At the same time a process has been initiated to ensure long term habitat improvement in the region. The project aimed to construct 1400 dwelling units in 100 villages and set up building material based enterprises.

MATERIAL USAGE & CONSTRUCTION SYSTEM

<table>
<thead>
<tr>
<th>TYPOLOGY</th>
<th>Detached individual &quot;core houses&quot;.</th>
</tr>
</thead>
<tbody>
<tr>
<td>STRUCTURE</td>
<td>Precast RCC members.</td>
</tr>
<tr>
<td>ROOFING SYSTEM</td>
<td>Flat roof with precast ferrocement channels.</td>
</tr>
<tr>
<td>WALLING SYSTEM</td>
<td>Hydifoam masonry blocks manufactured locally.</td>
</tr>
<tr>
<td>DOOR/WINDOWS</td>
<td>Precast RCC frames and shading device.</td>
</tr>
<tr>
<td>FLOOR</td>
<td>Laterite masonry rock foundation.</td>
</tr>
</tbody>
</table>

POST-TSUNAMI RECONSTRUCTION WORK
RIDIYAGAMA HOUSING SCHEME, AMBALANTOTA, SRI LANKA

This housing scheme is for 30 families near the coast in Sri Lanka. The Samadhi Foundation provided these houses for tsunami victims, most of them belonging to a low-income community of fishermen from Ambalantota. Similarly oriented single-storey houses of about 46 m² floor area are built in a row.

MATERIAL USAGE & CONSTRUCTION SYSTEM

<table>
<thead>
<tr>
<th>TYPOLOGY</th>
<th>Detached individual houses.</th>
</tr>
</thead>
<tbody>
<tr>
<td>STRUCTURE</td>
<td>Compressed earth brick columns.</td>
</tr>
<tr>
<td>ROOFING SYSTEM</td>
<td>A sloping roof that uses local cured timber for understructure of the clay tile cladding.</td>
</tr>
<tr>
<td>WALLING SYSTEM</td>
<td>The rammed earth walls which are made with cement-stabilised earth are constructed with steel slip formwork.</td>
</tr>
<tr>
<td>DOOR/WINDOWS</td>
<td>Timber door and window frames.</td>
</tr>
</tbody>
</table>

LCCR FEATURES

Use of local materials:
- Appropriate choices of local material for this rural area as material transport costs would be high, while labour intensive and environmentally friendly building methods are more cost-effective.

Ventilation:
- Inside the house, the cross ventilation is good.

Orientation:
- The openings of the house are well orientated to the north and south facades, with none to the east or west.

Rain sheltering:
- The sloping roof overhang provides good shelter from the rain as well as solar protection during the summer.

KNOWLEDGE DEVELOPMENT AND DISSEMINATION FOR PROMOTING LOW CARBON CONSTRUCTION IN THE RURAL AREAS AND SMALL TOWNS OF INDIA AND SOUTH ASIA
After the devastating Kosi floods of 2008 the people of Orlaha and Puraini of Supaul district, Bihar, reconstructed 45 and 69 houses respectively. Indigenous labour intensive construction techniques and materials were used to build bamboo houses that incorporated flood, earthquake and cyclone resistant features.

**MATERIAL USAGE & CONSTRUCTION SYSTEM**

<table>
<thead>
<tr>
<th>TYPOLOGY</th>
<th>Detached individual houses of 25-30 m².</th>
</tr>
</thead>
<tbody>
<tr>
<td>STRUCTURE</td>
<td>Precast RCC pile foundations</td>
</tr>
<tr>
<td></td>
<td>Superstructure of well-connected bamboo frame. The different types of joints in the house were secured with three types of lashings (tying with rope) with a bamboo pin to provide rigidity wherever necessary.</td>
</tr>
<tr>
<td>ROOFING SYSTEM</td>
<td>Bamboo rafters were used in the roof.</td>
</tr>
<tr>
<td>WALLING SYSTEM</td>
<td>Bamboo mesh was used in the walls that were constructed in wattle and daub technique.</td>
</tr>
<tr>
<td>SEMI-OUTDOOR SPACES</td>
<td>Some of the units have shaded verandas.</td>
</tr>
</tbody>
</table>

**LCCR FEATURES**

- **Local material usage:**
  - Use of local bamboo and earth reduces transportation costs.

- **Disaster resistance:**
  - The connectivity of the plinth through the walls to the roof prevents uprooting during storms.
  - Plinths are built higher than the average annual flood level. Attic space is used not only for storage but also refuge from floods.

- **Sanitation:**
  - Eco-san toilets have been installed in most houses.

- **Renewable energy:**
  - Solar lights have been installed.