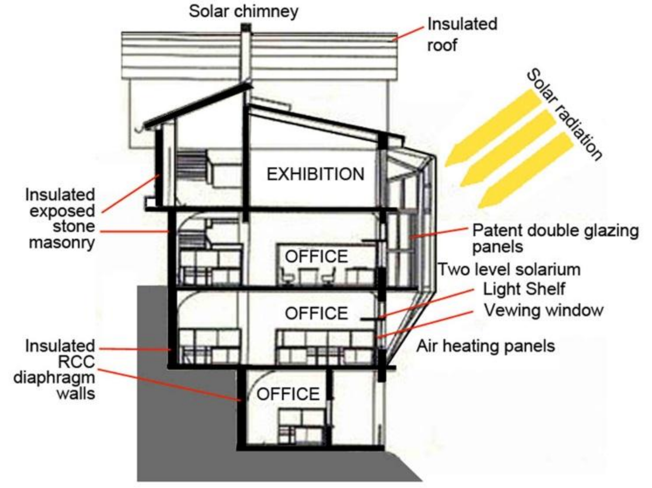
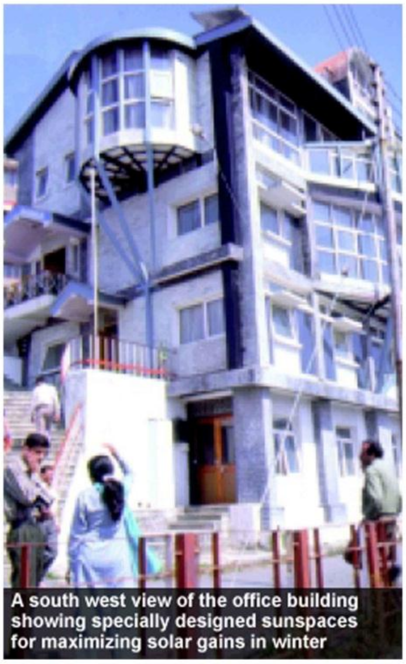
HIMURJA OFFICE BUILDING
SHIMLA, HIMACHAL PRADESH

The Himurja building is a multi-storeyed office that is located on a sharply sloping site and employs a number of passive solar strategies well suited for the climate of Shimla. It is also a good example of how to integrate renewable energy systems into the design of a building.

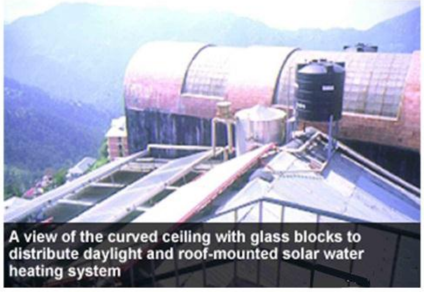
Building feature	Description
Typology	4 storeys building of built up area 635 m^2 terraced with an existing building. The ground and first floor are coupled with the earth.
Structure	RCC structure
Roof system	Well insulated sloping roof clad with metal sheets and ideally oriented solar panels.
Wall system	Stone masonry in exposed walls, while insulated RCC diaphragm walls coupled with the earth. All external walls have good insulation of 5 cm thick glass wool.
Door/windows	South facing openings of double glazed panels and hard plastic windows in some faces.
Buffer spaces	South facing solarium



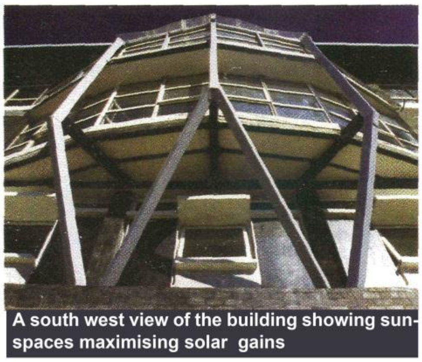
Section demonstrating various passive solar features integrated into the building envelope



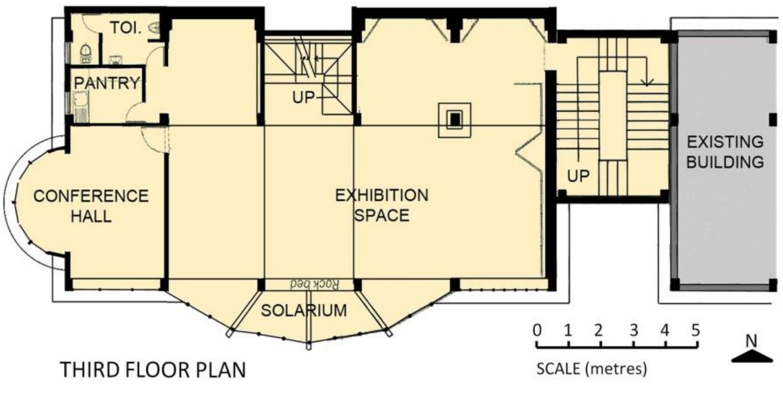
A south west view of the office building showing specially designed sunspaces for maximizing solar gains in winter



A view of the curved ceiling with glass blocks to distribute daylight and roof-mounted solar water heating system



A south west view of the building showing sun-spaces maximising solar gains



Floor plan of the Himurja Office building

DESIGN FEATURES:

Siting and orientation:

- The building is set into the slope of the site and the orientation provides maximum exposure to the south side.

Thermal Strategy:

- Coupling the ground and first floor with the earth prevents heat loss to a great extent.
- With most openings on the south and west facades, the building maximises solar gain.
- The plan of the building and its three dimensional form allow maximum penetration of sun maximising both solar heat gain and daylight.
- The judiciously designed thermal mass absorbs and provides heat in the spaces throughout the day.
- Air heating panels designed as an integral part of the southern wall panels provide effective heat gain. Distribution of heat gain in the entire building is achieved through a connective loop.

Ventilation:

- To optimize ventilation during summer, the connective loop is coupled with solar chimneys designed as an integral part of the roof.

Buffer spaces:

- A solarium (sunspace) is built as an integral part of the southern wall maximising heat gain.

Daylight design:

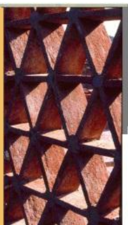
- Distribution of daylight in spaces is achieved through careful integration of window and light shelves.
- Light reflected off the light shelves is distributed into the deep plan of the building by designing a ceiling profile that provides effective reflectivity.
- Artificial lighting is seldom required (except during dark sky conditions sometimes in winters) in the south oriented spaces, which are well day-lit during working hours.

Insulation:

- Good insulation of 5cm thick glass wool in RCC diaphragm walls prevents heat loss.
- Infiltration losses are minimised through weather-proofed (with no thermal bridges) hard plastic windows.
- Double glazing helps control heat loss from glazing without creating any internal condensation.

Renewable energy systems:

- The photovoltaic system of 1.5 kWp meets the energy demand for lighting whenever required. Roof-mounted solar water system (1000 litre per day) has been used in the building. The water is circulated through radiators for space heating especially in the northern spaces.



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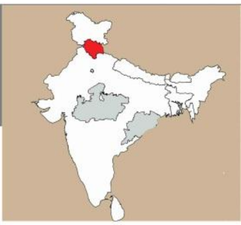
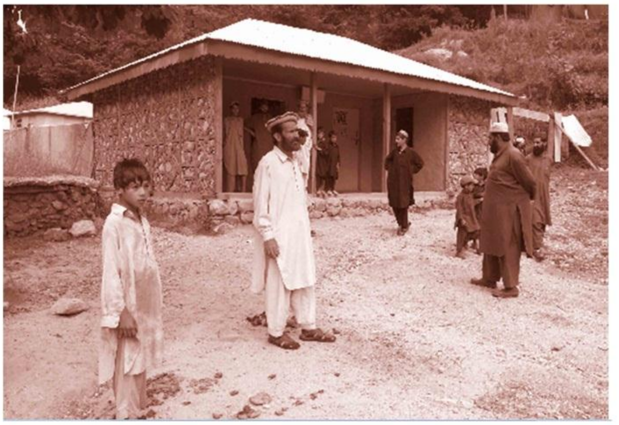
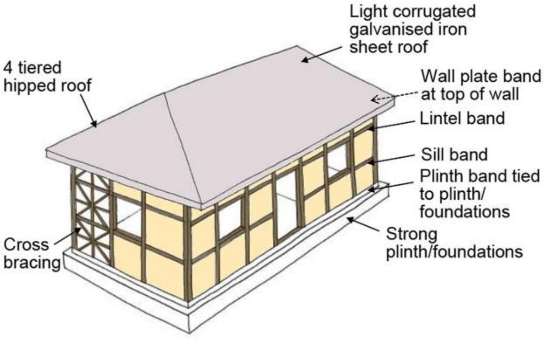


POST-EARTHQUAKE RECONSTRUCTION WORK
PAKISTAN

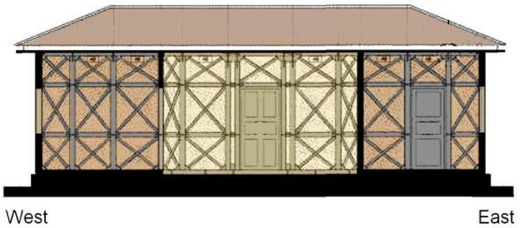
Since it was noted that during the 2005 earthquake in Kashmir, buildings constructed using traditional methods held up much better than did many modern structures, in the rural owner-driven reconstruction work that followed, the use of the *Dhajji Dewari* technology was promoted and facilitated. *Dhajji Dewari* which uses complete timber frame with masonry forming panels within the frame, performed very well since although there were many cracks in the masonry infill, most of these structures did not collapse, thereby preventing the loss of life. Hence,It was rapidly adopted by local communities. Not only do these construction techniques stand up well in earthquakes (when properly constructed), but they also make economical use of local materials like wood, stone and mud, having low environmental impact, and are part of the local housing culture and know-how.

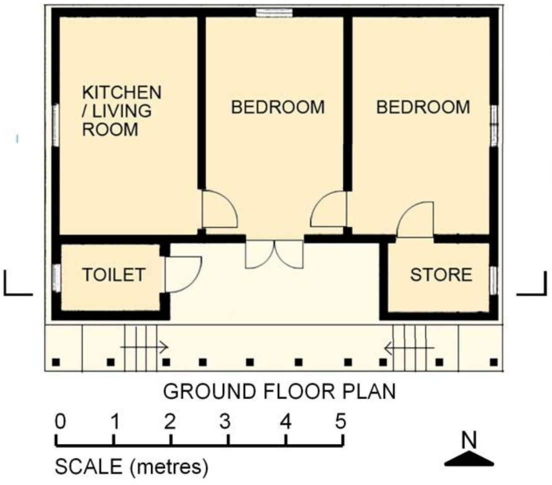


Building feature	Description
Typology	The dwellings are of single storey detached houses, gross area of 70m², gross internal area of 46m².
Structure	RCC foundation and plinth with a superstructure of locally available timber columns and beams.
Roof system	Pitched roofs with rafters and purlins made of locally available slender timbers. Roof covering was done with CGI sheets.
Wall system	Dhajji dewari system of timber bracing with an infill of stone masonry that is mud plastered.
Door/windows	Openings are timber frames and well integrated into the *dhajji-dewari* wall cross bracing system.
Buffer spaces	South facing veranda



The housing prototype that was replicated





Section and plan of the prototype

DESIGN FEATURES:

Thermal strategy:

- The south facing verandah is a buffer space and also brings in sunlight into the dwelling.

Rain sheltering:

- This can be done through Sloping roof with overhang and RCC plinth protects timber from water.

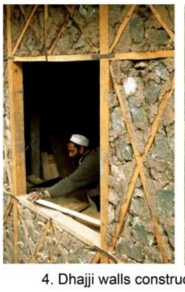
Earthquake resistance:

- Small timber bracing members distribute earthquake forces evenly across the wall. This is further dissipated in the friction of the bracing moving against stone infill.
- The reinforced foundation provides a stable base, which minimizes chances of structural failure in an earthquake.
- The roofing is lightweight with timber truss and CGI sheets reducing load.

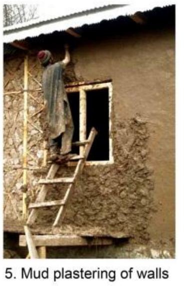
1. RCC plinth constructed.

2. Timber framework of walls and roof erected

3. Tin roof cladding fastened over roof structure



4. Dhajji walls constructed. Timber framework and cross bracing are filled in with stone



5. Mud plastering of walls

Stages of construction of one of the housing prototypes.

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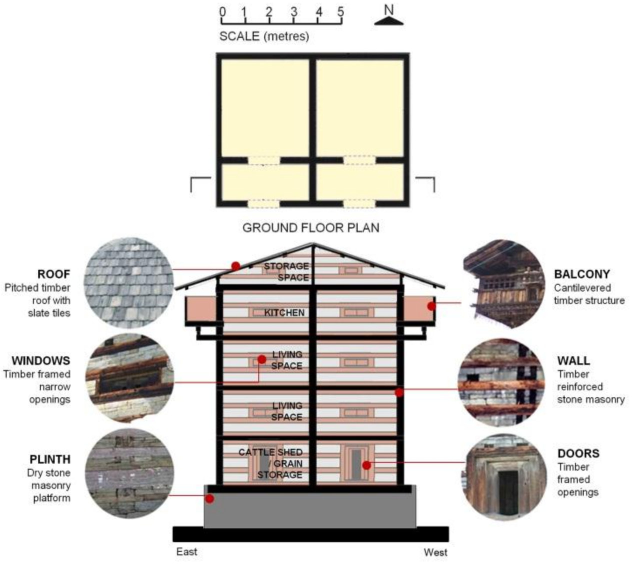
KOTI BANAL ARCHITECTURE
UTTARAKHAND AND HIMACHAL PRADESH

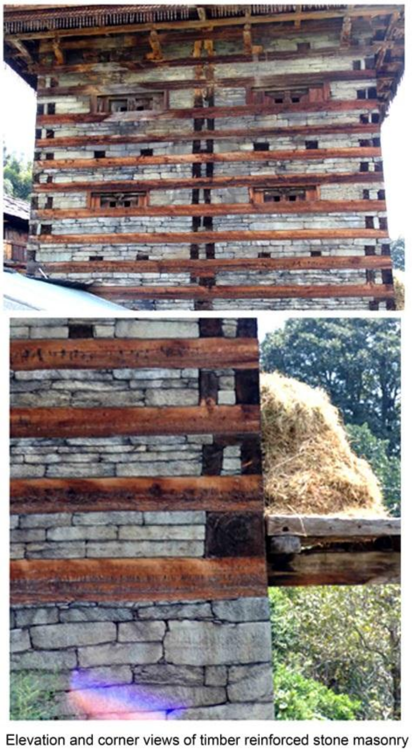
In the Rajgarhi area of Uttarkashi district of Uttarakhand, India a large number of intact buildings of a distinct earthquake resistant construction type known as Koti Banal can be found. This construction type has been in practice for more than 200 years and it is reported that Koti Banal architecture withstood and performed well during many past damaging earthquakes in the region (eg. 1991 Uttarkashi quake of magnitude 6.6 on the Richter scale). These buildings are considered as the basics of modern earthquake-resistant design.


A typical Koti banal building located in the Rajgarhi area; a sketch taken from Middlemiss (1910) illustrating structures of this type in the Kangra Valley

Building feature	Description
Typology	Multi-storied detached structures of height varying between 7 and 12 metre above the plinth. They have rectangular plan configurations with the lengths and widths varying from 4-8 meters.
Structure	The buildings rest upon a raised dry stone masonry platform over the foundation made in rubble masonry. In the lower part, the walls consist of a configuration with orthogonally arranged wooden logs interconnected at the junctions by wooden pins/tenons. For the two bottom-most layers single wooden logs while for the upper layers double wooden logs are used. The infill between the logs is furnished with well-dressed flat stones which are dry-packed or by using a paste of pulses (lentils) as mortar. This wooden structure is not used for the upper parts of the wall where the dressed stones have a load-bearing function. The structure is further reinforced by wooden beams which are perpendicular to the wooden logs at the middle of the walls connecting two parallel outer walls.
Roof system	Typically, the roofing span is half of the building width. The roof construction consists of a wooden frame which is expected to act as a flexible diaphragm and is clad with slate tiles.
Wall system	50-60 cm thick timber-reinforced stone masonry. The thickness of the walls is determined by the thickness of the two parallel arranged wooden logs.
Door/windows	A single small door access on the ground floor and relatively small south facing windows floors above with wooden frames and shutters.
Floor	Wooden beams and planks resting on wooden joists supported by beams or walls.
Semi-outdoor spaces	The upper two floors have balconies running around the whole building cantilevering from the wooden logs of the flooring system with a wooden railing.



Plan and section of a typical dwelling unit.



Elevation and corner views of timber reinforced stone masonry

DESIGN FEATURES:

Siting and orientation:

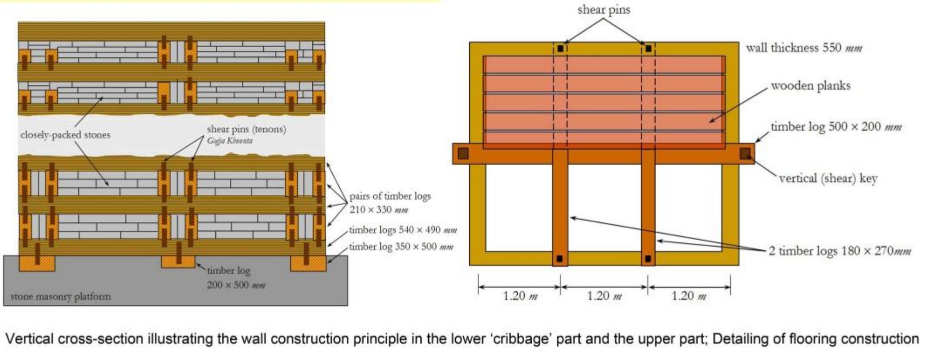
- Situated on a firm ridge or plane ground having rock outcrop without any buildings in the immediate vicinity.

Thermal strategy:

- High thermal mass of building envelope retains heat.
- Small window openings prevent heat loss and are south-facing.
- Low floor height (2.2 - 2.5 meters), reduces the internal volume of air to be heated.
- The attic space acts a thermal buffer.

Earthquake resistance:

- Regular plans and elevation shapes, integration of wooden beams over the total height of the building, small opening size and the arrangement of shear walls.
- Walls are strengthened against out-of-plane failure by a shear key in the form of a wooden member which runs vertically through the storeys and is structurally connected to the timber framing of the building.
- For lateral load resistance (horizontal), pairs of wooden logs connected to each other by wooden shear pins/tenons form a wooden frame which is braced by well-dressed flat stone masonry.
- The dry stones masonry between the logs enables a certain level of flexibility and allows lateral deflections of the building without damage effects.



Vertical cross-section illustrating the wall construction principle in the lower 'cribbage' part and the upper part; Detailing of flooring construction

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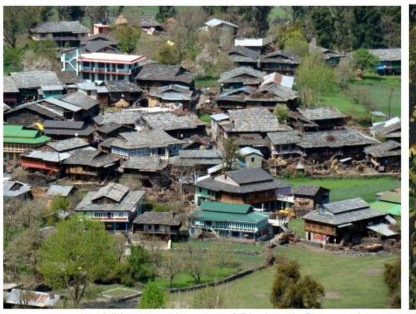
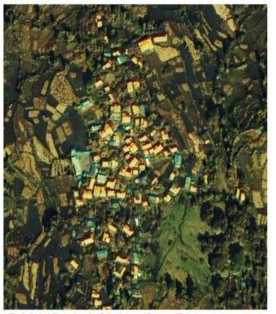
DWELLING UNIT TYPOLOGY OF BHALYANI SETTLEMENT
KULLU, HIMACHAL PRADESH

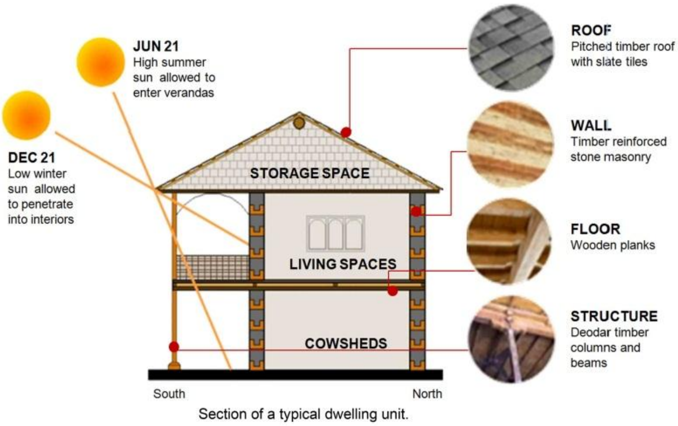
The traditional village settlement of Bhalyani, in the hilly Kullu district, situated in the Lug valley, at an altitude of 1952 metres above sea level. The settlement has a compact layout with dwellings connected by narrow pathways and clustered around courtyards. These traditional dwellings evolved out of the functional requirements of the locals, the availability of the suitable building materials and construction techniques developed over the centuries to provide comfort to the occupants from the extreme cold.



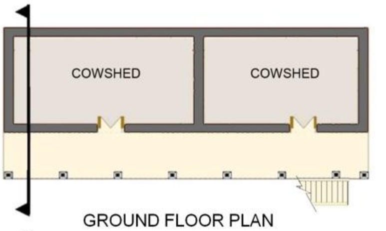


Village settlement of Bhalyani, Source: Imagery@2011Digital Globe, Geo Eye

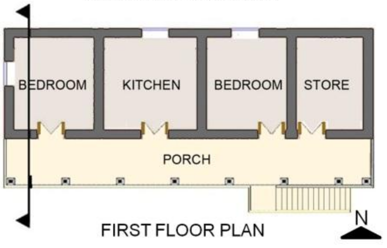
Building feature	Description
Typology	Two storey high detached houses with linear arrangement of rooms, connected by verandah / balcony, in both the floors.
Structure	Locally available 'Deodar' timber columns and beams that frame the thick walls. The plinth is of random rubble masonry.
Roof system	Pitched roofs with rafters and purlins made of locally available slender timber. Roof covering is slate tile from locally available stones. Below the roof, a ceiling was constructed with timber. The attic in between is used for storing food-grains. U value: 2.1 W/m^2K
Wall system	The walls are made of stone masonry and timber having thickness of 45-60 cm. This traditional style of wall construction is known as '*Kath-Khuni*' i.e. the systematic process of layering and structural interlocking of timber and stone masonry. **U value: high thermal capacity and low conductivity (kvalue in W/m ºC) – for hard timber 0.16 and for sandstone 1.295.**
Door/windows	Small size openings are provided in the rooms of the dwellings with timber and glass shutters. Openings are mostly provided on east, west and southern walls.
Floor	On the ground level, mud & cow-dung are used for flooring. The upper levels, floors are made of timber planks and joists.
Buffer spaces	Sun-space or solarium by enclosing the first floor veranda.



Section of a typical dwelling unit.



GROUND FLOOR PLAN



FIRST FLOOR PLAN

DESIGN FEATURES:

Siting and orientation:

- Large exposure to the south side for maximum solar gain.
- Compact settlement layout to reduce heat loss.

Thermal strategy:

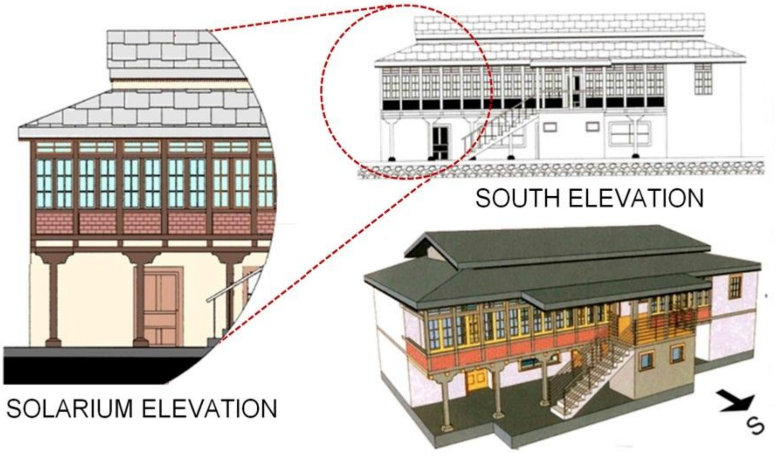
- Low floor height (2.1 - 2.4 m) keeps the surface-to-volume ratio low and reduces heat loss from exposed surfaces.
- A south facing solarium maximises heat gain during day time and prevents heat loss at night.
- The timber and stone construction has high thermal capacity and low conductivity and allows a very good thermal insulation by providing high time-lag of more than 8 hours. This makes the interior of the house cooler in summer and warm in winter for maximum part of the year. The use of timber also prevents / reduces heat-gain and heat-loss through floors to a great extent.
- The attic space acts as a thermal buffer.
- The location of the kitchen on the upper floor allows dissipation of heat into other spaces keeping the indoors warm even at night.

Rain protection:

- Being a hilly terrain, the natural contour / slope of the hilly terrain drains rain-water. The projection of the low pitched roof and the solarium protects the floors below.

Earthquake resistance:

- The technique of wall construction with timber framing and the regular plan of the buildings braced with internal cross walls enhance resistance to seismic damage.



SOLARIUM ELEVATION

SOUTH ELEVATION

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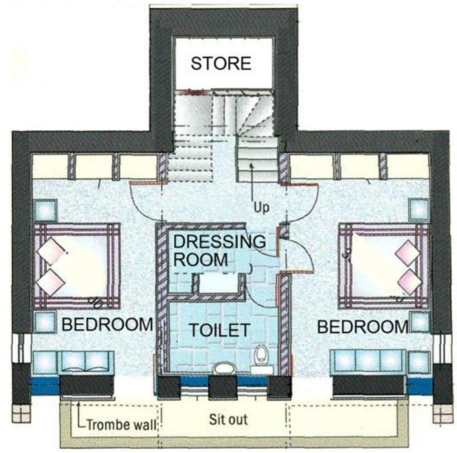
MOHINI MULLICK'S RESIDENCE
BHOWALI, NAINITAL, UTTARANCHAL

This residential building is an example of traditional hill architecture that maximises the use of solar energy to meet its operational needs.

Building feature	Description
Typology	A double storey detached house with the ground floor coupled with the earth and built-up area of 100 m^2
Structure	The structure is a load-bearing construction with a timber-framed roof.
Roof system	South sloping timber roof clad with local stone tiles insulated with rock wool.
Wall system	The walls of the house are thick random rubble made from rubble available near the site. The joints are in cement mortar but kept very lean so as to give the look of dry rubble masonry.
Door/windows	South facing openings.
Floor	Wooden planks.
Buffer spaces	The buffer spaces (lobby, stairs, etc) are on the north and there is a south facing trombe wall.



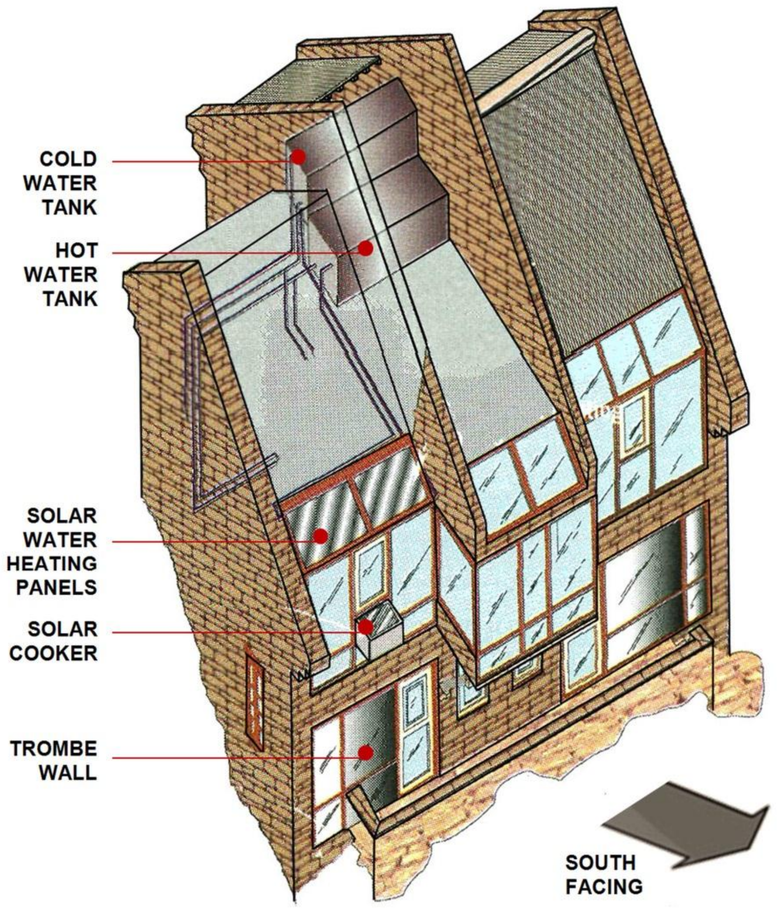
GROUND FLOOR PLAN

0 1 2 3 4 5

SCALE (metres)

N

Plan



DESIGN FEATURES:

Siting and orientation:

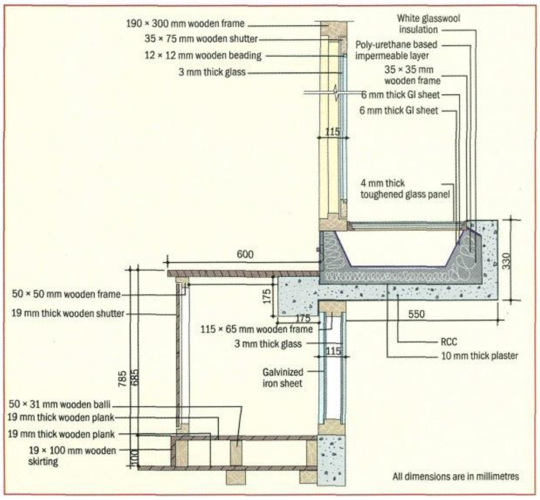
- The compact shape of the cottage reduces heat loss and the orientation of most of the living spaces to the south maximizes solar gain.

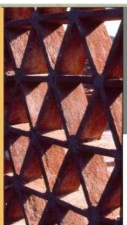
Thermal strategy:

- Direct solar gain for living/dining room and kitchen by large south facing glazed areas and indirect solar gain for night use spaces.
- An air lock at the entrance acts as a buffer for north facing spaces.
- On the north side, the house is set partly into the hill which provides earth coupling from lower floor and stabilises internal temperatures.
- Minimum openings on the east and west and no openings on the north.
- Trombe wall on the south side warms up both bedrooms.
- The roof is insulated with rock wool.

Renewable energy systems:

- A 100 litre- roof integrated solar hot water collector system with the tanks located in the attic spaces.
- A wall-integrated counter top operated solar food warmer/cooker is provided for the kitchen.





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