



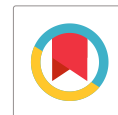
# Architecture of Uttarakhand and Construction Techniques for Affordable Housing

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## ABSTRACT

A large part of the population in Uttarakhand lives in rural areas and is deprived of the basic human need of a decent shelter. Such a scenario is observed in almost all the parts of India. Various housing programs are initiated from time-to-time by the government to provide better living conditions to the rural population at an affordable range in terms of cost and size of the dwelling unit. But 'one size does not fit all'. There is a need to provide safe, durable, comfortable and low cost housing solutions considering the local geo-climatic conditions, living habits and socio-economic conditions of the local people. The vernacular and traditional architectural styles in Uttarakhand, both in the Kumaon and Garhwal regions provide a base to understand the prevalent rural housing typologies along with the building volume, scale and orientation. Through intensive study it is found that most of the existing rural houses lack the basic necessities of light, ventilation, services like water supply and sanitation, proper relationship between interior- exterior spaces and resistance to hazards like earthquake and floods. CSIR- CBRI has developed and constructed environment friendly prototype of an affordable dwelling unit for Uttarakhand region with the help of innovative materials and construction techniques to provide a low cost, energy efficient, comfortable and disaster resistant house. It also addresses the shortage of the conventional building materials in the region. The building technology used is easily adoptable and may be implemented with the help of local labour which shall help to generate employment.

**Keywords:** Affordable housing; Low cost construction techniques; Vernacular architecture.

## 1. INTRODUCTION

According to the 2011 census, around 68.84% of population in India lives in the rural areas. In Uttarakhand alone 69.77% of people reside in the villages of rural areas under poor living conditions and with bare minimum services. Many National housing programs by the government are initiated from time-to-time to provide better living conditions for people both in the rural and urban areas. But such interventions are rarely adequate or suitable as 'same size does not fit all'. The percentage of BPL persons in Uttarakhand stands at 39.6% as compared to the all-India proportion of 27.5% as per the Census 2011. The percentage of the BPL families in rural areas is at 40.8% against 36.5% in the urban areas. Also, as per surveys for IAY, the housing shortage in Uttarakhand is about 0.55 lakhs houses against the overall shortage of 111.19 lakhs. Therefore to cater to the housing needs of the poor people in the rural areas, there is a need to come out with easily adoptable and affordable solutions to counter the ever increasing housing shortage in Uttarakhand.

The state of Uttarakhand is divided into two regions namely the Garhwal and Kumaon region. The vernacular and traditional architectural styles of these regions are slightly different even though both the regions consist of the hilly areas and the plain foothill

areas. The difference is based on the cultural differences and the availability of the building materials. Most of the people live in vernacular houses locally constructed by using conventional building materials like mud, stone and timber. These dwelling units lack proper light, ventilation, services like water supply and sanitation and have inadequate resistance to hazards like earthquake. There is also a shortage of conventional building materials once it comes to providing rural mass housing.

This paper discusses the prevailing construction typologies of Uttarakhand and proposes a prototype to provide better living conditions at low cost, considering the local geo-climatic conditions, socio-economic status and the living habits of the people of Uttarakhand while addressing the shortage of the conventional building materials. Also, the purpose of this research is to identify and promote innovative materials and construction techniques, which are easily adoptable, region specific, promote energy efficiency and generate employment for the people.

## 2. VERNACULAR ARCHITECTURE OF UTTARAKHAND

Uttarakhand lies in the northern part of India and extends from the Tons- Yamuna river in the west to Kali river in the east. The west boundary of the state is

bound with Himachal Pradesh and formed by Supin, Tons and Yamuna. The southern extend lies in the plains of western Uttar Pradesh while to the North is the region of Tibet. Uttarakhand is frequently visited by tourist, pilgrims, hermits, writers, naturalists and environmentalists as it is a treasure of natural beauty, diverse flora and fauna and a home to sacred temples and monasteries. There are many ancient temples and buildings in the region which were constructed over a period of time under the influence of the local culture, topography, materials available, geo-climatic conditions, and seismic activity. The Garhwal and the Kumaon regions have different local languages, culture and traditions. The building styles have also evolved independently in both the regions due to such differences.

## 2.1 Kumaon Region

This region comprises of the districts of Chamoli, Dehradun, Haridwar, Pauri Garhwal, Rudraprayag, Tehri Garhwal and Uttarkashi. The characteristic features of the traditional architecture found in this region are dictated by the immense availability of stone and timber in the areas. The walls are typically made of stone while timber is used for the structural purposes and the slates are used for roofing. The floors are made of wooden planks or mud, for insulation and occasionally stone slabs are also used.

The buildings are placed along the contours in the stepped terraces with large openings in front of the building and the waste drains in the rear part. The orientation of the houses are kept towards the east, south and west directions to get the benefit of the maximum direct sunlight. To receive sunlight at the rear part of the buildings also, the height and the spaces between them are graded.

The most unique feature of the Kumaon building typology is the interior space organization and design. It is same irrespective of the economic class of the owner or the status in the society. The difference is only in the decoration of the entrance (Kholi) and slight variation in the sizes of the rooms and wood carvings. The sloping roof of slate and the intricate wooden carvings on the doors and windows give coherence and unity to the elements of the building. There is usually no change in the design of the houses even when two units are placed together.

The design of the typical traditional house i.e. the 'Kholi' has the entry from the centre of the house dividing the house into two parts. Over time, both the parts have evolved into two separate units on either side of the stairs. The ground floor is called 'Goth' and is meant for cattle, fodder and storage. This helps to give warmth to the upper floors where the people reside. The living areas on the first floor have a sitting area in the front (Chakh) and a multi-purpose middle room

(Majhala) with a central wooden non-structural pillar. The kitchen is in the attic or top floor which is approached by a wooden ladder and is ventilated through the holes in the roof slates. For storage, the space below the stair landings are used as stores (Kotharis) and loft above the chakh. To conserve the natural warmth in winters the height of the floors especially of Goth, kitchen and lofts are kept very low. Openings are kept very small for the similar reasons.



Fig. 1: Typical house from Kumaon region.

These compact traditional buildings are visually harmonious with their surroundings but they lack in the basic sense of the interior- exterior spaces relationships. This is apparently because of the cellular compactness of the utility spaces. The spaces even have inadequate light and ventilation.

## 2.2 Garhwal Region

This region comprises of the district of Almora, Bageshwar, Champawat, Nainital, Pithoragarh, and Udham Singh Nagar. The houses in this region are placed after careful site selection usually enroute to the pilgrim centers, near sources of water and in the areas which provide protection from the cold winds in winter. The traditional houses are built along the contours of the hills and are generally of two or three floors, having a rectangular plan.



Fig. 2: Typical house from Garhwal region.

The living and cooking areas have low height and are provided above the cattle space, fuel and fodder

space to provide warmth in winters. Approach to the living areas on the first floor is through the staircase on the side of the house. The balcony mostly 75cm in width in front of the house forms an integral part of the building. Construction materials like stone, wood and slate are used extensively as they are locally available and easy to handle using manual tools, equipments and manual labour. A wooden structural frame is made and locally available stone is infilled for making the walls. The beams and columns made of timber are intricately carved to improve the aesthetics. Floors and ceiling of the building are also made from the wooden planks. The sloping roofs are made with slates and are supported over wooden trusses.

The 'Kothar' or the grain storage structure symbolizes the affluence of the family and is located near the house. These are wooden structures placed 1.0m above the ground level with a small gap all-around the rectangular structure to keep it isolated so that the grains do not get damaged easily.

At some strategic locations, 7-8 storied tall wooden structures were made with timer frames called 'Sumers'. These structures dominate the skyline and served as emergency shelters, watch towers, place of village diety and as a landmark for the town. Such structures are more than 200 years old and have sustained the seismic activities of the region. Sumers have a modular form and were made flexible enough to bear the tremors of an earthquake, with the floor to floor height extending from 1.5 to 1.8 m. In Garhwal region, the overall settlement and the built-forms incorporate multi-utilization of the stepped slopes cut through the hills, and is governed by the close relationship between the man and nature.

### 3. CONSTRUCTION TYPOLOGIES IN UTTARAKHAND

The vernacular architecture of Uttarakhand differs all throughout the state based on the geo-climatic conditions and the local materials used for construction. The major factors which guide the construction typologies in the state are the a) climate, b) materials available for construction and their techniques used, c) spending capacity of the people or affordability, d) features used against flood/ snow/ earthquake resistance, e) living habits, f) ease of maintenance and environment friendly g) use of aesthetical and architectural features. The construction typologies can be divided into three physiological zones of foothills, low level hilly regions, and mountainous regions.

#### 3.1 Foothills

The basic factors which guide the local architecture of this zone are: a) availability of good quality top soil, b) warm temperatures and moderate level

of precipitation c) agricultural residue, d) easy availability of non- local materials. When a house is made within a short period of time usually for extension, the low cost technology of using the agricultural waste is used for construction. A lot of agricultural waste is available in the low lying plains, which is used for making walls with mud. The left over from the harvest of wheat, corn, barley etc are used for this purpose. The roof covering material is also the thatch from harvests of sugarcane or some dried wild grass, while timber is used as the structural frame for the roof supported by the walls.

**Table 1. Building construction systems in the foothills.**

	System 1	System 2	System 3	System 4
Walling	Vegetal	Mud	Mud	Brick
Roofing	Thatch	Thatch, CGI, AC	Mud on wood	Reinf. Brick or RC slab, CGI

The better level of construction technology used in this region for making houses is through the use of hand-made sun dried bricks called 'Cob'. The cob walls are load bearing and are made with bricks similar in size to that of the burnt bricks. The roof is made of thatch which is costlier for a poor family as it requires frequent maintenance. Another type of roofing system that is used is with mud layering over timber deck supported by mud walls. Houses with such type of construction are decades old as the timber is very costly now.

Recently in the past few decades, kiln brunt bricks are used in place of un-burnt mud bricks, laid in mud mortar as well as cement mortar. The flat roofs made with mud and timber is replaced with GI sheets, which are sometimes preferred for their durability but were otherwise disliked for the uncomfortable interior environment under extreme climates. With the passage of time these roofs with GI sheets have been further replaced by RCC flat slab roofs especially around the plain areas of Roorkee and Haridwar.

#### 3.2 Low-level Hilly Regions

The basic factors which guide the local architecture of this zone are: a) easy access to building quality stone b) limited availability of good quality top soil, c) varying availability of timber and of water, d) moderate precipitation with no snow in winters. The Coursed Random Rubble (RR) masonry is used commonly for load bearing walls. The walls are usually built without mud plaster due to limited availability of the soil suitable as mortar and plaster.

The flat roof can be seen in this region usually along the western boundary of the state around Himachal Pradesh, as there is relatively less precipitation. In other

areas of the state, where pathal is easily available Pitched Pathal roofs (stone on timber) are used. This option is preferred over flat roof in the areas eastwards from the Himachal Pradesh border of Uttarakhand, due to marginal increase in the precipitation.

**Table 2. Building construction systems in low- level hilly regions.**

	System 1	System 2	System 3	System 4
Walling	Random Rubble	Random Rubble	Random Rubble	Brick Masonry
Roofing	Mud on wood	Pathal	RC slab	CGI, RC slab

In the past few decades, due to the increasing prices of timber and easy availability of modern building materials like cement, CGI sheets and steel, RCC roofs over stone walls are preferred. People with more resources prefer load bearing walls with bricks and cement mortar and RCC slab roofs.

### 3.3 Mountainous Regions

The basic factors which guide the local architecture of this zone are: a) easy access to building quality stone b) limited availability of good quality top soil, c) varying availability of timber and of water, d) extreme cold and snow in winter, e) increased seismic activity. Coursed/ Uncoursed Random Rubble masonry is most commonly used with or without mud mortar due to varying availability of water. Though, mud or cement plastering on the walls can be seen. Mostly two-way or four-way Pitched Pathal roof is constructed with a timber under-structure. The roof covering used is either slate/tile/ pathal in varying thicknesses from 10 mm to 50 mm.

**Table 3: Building construction systems in Mountainous regions.**

	System 1	System 2
Walling	Random Rubble	Brick Masonry
Roofing	Stone tile - Slate or Pathal, CGI, RC	Reinforced Concrete

In the past few years, due to the increasing cost of timber, CGI sheets are used for roofing as they are easy to install and are durable, but they are climatically disliked especially in cold winters. Flat RCC roof are also constructed in some places as it gives more flat work space in the hilly terrain.

## 4. DEVELOPMENT OF THE PROTOTYPE

CSIR- CBRI has designed and constructed a prototype affordable housing unit, designed for the hilly areas and the plains of the Uttarakhand state of India. The design has evolved as a result of in-depth research on the available case studies for vernacular houses and low cost construction technologies. The identification and analysis of the appropriate technological options for affordable and disaster resistant, durable rural houses, suitable for the region was carried out to build the prototype.

### 4.1 Design

The prototype house is a two storey building with a plinth area of 24 sqm at plinth level and 30 sqm as the total area covered area. The design is for a family of 5 members based on the living habits, safety, comfort, space, function, energy efficiency and socio-economic requirements of the people of Uttarakhand. The entrance is provided from the middle of the house, segregating the living and the utility spaces. There are two multi-purpose living rooms on each floor. A large storage-cum-study or sleeping space for two is provided in the attic at the first floor approachable through a flight of stairs within the house. Since the flat slab RCC roof is preferred in the region, the design is also constrained by the type of roofing system. The spaces are well lit and ventilated through the appropriate positioning of the openings; this not only reduces the cost of operation by minimising the use of artificial light and fans in the day time but also provides a healthy environment.

### 4.2 Construction

The house is constructed using innovative new technologies and materials developed by CSIR-CBRI, which aim to provide durable and cost efficient options. The region specific requirements of the available materials and resources are considered for the construction of the proposed house. The construction system is divided into foundation, walling and roofing.

#### 4.2.1 Foundation

The foundation is laid by stone masonry blocks with corner reinforcements. This technology is developed by CSIR-CBRI, and is used where building quality stone and aggregate is easily available at cheaper rates. The irregular shaped stones are laid in steel moulds, over these stones; concrete is poured and compacted by using plate vibrators. Mass production of the stone/concrete blocks is possible in parallel stacks. After setting of the concrete a good exterior texture of the blocks is achieved.

#### 4.2.2 Walling Type

There are various systems that can be used for walling as a cost effective, easily available and durable solution. The alternatives that can be used for the walling system are a) Stone Concrete Blocks, b) Solid Concrete Blocks, c) Burnt Clay Bricks in English & Rat – trap Bond and d) Improved Random Rubble masonry. The solid concrete blocks are made with machines for mass production. A number of machines are available for making these blocks. It is a very popular walling technology and the blocks are now being produced by various Building Centers and private entrepreneurs. The solid concrete blocks are made with concrete using graded aggregate of sizes varying from 10mm to 40mm by manual process or by using an egg laying type machine. The machine is used for higher productivity, strength and finish. It can cast six blocks of 30x20x15 cm size in single operation with an output of 120 - 150blocks/hr.

#### 4.2.3 Roofing Type

Various options for roofing are available for the house. The following partially precast systems have been adopted in the proto type: a) Precast Brick Panel & RC Joists, b) Precast RC Planks & Joists and c) CGI Sheets. The precast brick panel & RC joist system is ideal for providing durable and economical roofing / flooring in the low cost houses where bricks are available locally otherwise RC Plank and Joist system can be adopted. This consists of partially precast RCC joists (13cmx10cm), supporting the prefabricated brick panels of size 53cmx120cm, having 6mm dia. ms bars (2Nos.) in each panel and is covered with 35mm thick cement concrete. By these systems the use of shuttering is eliminated. The 6mm diameter bars on each panel both-ways are provided over the panels before laying cement-concrete. This system offers saving of 25-30 percent against 115 mm thick RCC roof slab.

The Precast RC Planks & Joists system is used where the components are produced on casting platform at construction site. The size of precast RC plank is 30cm wide, 6cm thick, up to 150 cm long; precast RC joists 15 cm x 15cm and up to 3.6 m long. As soon as the walls reach the floor/roof level, the precast components are placed, and partly filled with concrete to form the floor\ roof. This results in 20% saving in overall cost, 25% in cement and 10% in steel as compared to conventional R.C. slab floor/roof.

Alternatively, the CGI sheets can also be opted for the roofing system. Though this is a cheaper option and is also durable but is not climatically acceptable by many people. In extreme cold or hot conditions an insulating layer of thermocole sheets or thatch panels can be provided under the CGI sheets.

#### 4.2.4 Additional Features

Additional features such as the integrated solar cooker, Earthquake resistant construction, Solar water heater & LED lights have been provided in the house. This shall not only ensure the comfort and security of the residents but also reduce the costs of operation. There is only one time installation cost. These also help improve the living environment of the people and provide sustainability through the use of renewable sources of energy.



**Fig. 3: Construction of the prototype in Rural Park at CBRI, Roorkee.**

#### 4.3 Cost

The proposed house with the total covered area of 30sqm costs Rs.1, 95,000/- at the current cost of Rs.650/- per sq. feet. There will be only one time cost for the installation of the various systems to construct the house as discussed above, with no significant maintenance costs. The life span of the prototype is estimated to be around 50 years. About 30% reduction in construction cost by using alternate construction systems compared to conventional houses.

**Table 4: Saving in cost, time and energy of the proposed house.**

Technique	Saving in Cost	Saving in Time	Energy Saving
<b>ROOFING TYPE</b>			
RCC Slab (Conventional)	0	0	0
RC Plank Roof	20 – 25%	75%	20%
Brick Panel Roof	25 – 30%	75%	5%
<b>WALLING TYPE</b>			
230 mm brick wall (Conventional)	0	0	0
Stone Block wall	20	20	60%
C- Brick Wall	15	-	60%
Rat Trap Bond	20	-	25%

## 5. CONCLUSION

The combination of the architecture of Uttarakhand and innovative construction techniques for affordable housing are taken as the basis for the development of the prototype to provide a low cost, energy efficient, disaster resistant environment friendly and durable housing to the people of the state. The house is designed for a family of five people, considering the living habits, geo-climatic conditions of the region, culture and the availability of materials. Most techniques used for building the house are taken from the technology developed at CSIR- CBRI. Several innovative materials & construction techniques have been developed for a wide variety of applications in buildings, especially in low cost mass housing programmes in rural and semi-urban areas. These material and techniques are effective, affordable and easily adoptable. Their adoption adds to improvement in the housing environment as well as improvement in the quality of life of the people. This design may be implemented with local labour and is therefore amenable to the economic condition of the villagers.

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## CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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## REFERENCES

- Garg, R. K., Garg, N. K. and Batra, Y. K., Sanitation and Waste Water Disposal Systems in Rural Areas, Seminar on "Up-gradation of Housing & Amenities in Rural Areas", December, 22<sup>nd</sup>-23<sup>rd</sup> 2004 at Bhubaneswar, *Journal of Indian Building Congress*, 11(2), (2004).
- Verma, N., CBRI Building Research Note No. 34 on Low Cost Sanitation for Rural & Urban Houses,. 1985.
- Pot-Panel Roofing/Flooring Technique, CBRI - News Letter, 14(3),(1998).
- Faster Production of Stone Blocks and Concrete Blocks, CBRI-Annual Report, 1999- 2000.
- Hira, B. N. and Negi, S. K., Innovative Building Techniques for Mass Housing Problems in India; Indian Habitat and Infrastructure – Need for Innovative Approach, 25<sup>th</sup> & 26<sup>th</sup> September 2003.
- Hira, B. N. and Negi, S. K., Seminar on "Up-gradation of Housing & Amenities in Rural Areas", December, 22<sup>nd</sup>-23<sup>rd</sup> 2004 at Bhubaneswar appropriate Building Techniques for Rural Housing, *Journal of Indian Building Congress*, 11(2), (2004).