



Review on vernacular construction methodologies and materials to create a sustainable retreat home in the hilly region of India.

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Abstract— This paper review on different types of vernacular house in hilly region of India which aims to draw from the knowledge of how vernacular house can work with the climate and local material providing techniques and design. It is also review on how traditional house were designed to provide human comfort, requirement and safety which utilized locally accessible building material and construction technology which are more responsive to the climate and geographic conditions. Basically this paper review on local materials, ventilation technique and construction technique of vernacular house dealing with any types of climate condition in hilly region of India.

Keywords— Vernacular house, Material, Traditional building technique, Bio-climatic, Sustainable, Conserve, Preserve, Indian hilly region.

I. INTRODUCTION

Vernacular house is a local or regional construction house usually used traditional materials and resources from that particular area which provide a comfortable place in quite hilly surroundings with nature. The basic goal of vernacular house is to make the best use of available resources, such the sun and wind. Vernacular structure stands strong and remains environmentally friendly for sustainable construction technique on checking the strength, stability and support. By analyzing various design strategies, building forms and appropriate building material, the exterior and interior design which can increase thermal comfort, reducing energy dependency of the house. The primary purpose of a structure is to provide its occupants with shelter and enough thermal and visual indoor comfort. A building's level of comfort is determined by its architecture material and the weather outside.

II. LITERATURE REVIEW

The planning, design, and construction considerations of India's mountainous regions are examined in this paper. The qualitative research methodology was applied in this paper. Using internet resources and secondary data from relevant sources, peer-reviewed journal articles and research papers the systematic review of the literature on the construction methods used in hilly locations has been explored by Chawhan, Vrushali, and Mohammad Arif Kamal[1]. The integrity of vernacular architecture must be maintained. As a result, historic architecture should not be disrupted and should instead be successfully merged with modern architecture. Using locally accessible building materials and construction technology that was more responsive to their particular climatic and geographic constraints, buildings were constructed to maximize human comfort by Sharma, Sandeep and Puneet Sharma[2]. The Kullu region of Himachal Pradesh's local building materials and modern construction methods were thoroughly researched by the authors. Vernacular structures built with local materials and construction methods respond better to their geoclimatic environment. Traditional building knowledge's lessons can be a very effective instrument for sustainable development. The potential policy needed for the preservation and protection of traditional building methods for sustainable development is discussed in the paper's conclusion by Panwar, Manoj, and Sandeep Sharma[3]. To determine how they respond to the bioclimatic elements, the various dwelling types in various Assam sites and one in Manipur, which has a macroclimate similar to the hilly parts of Assam, were examined. The study concentrated on the materials employed, ventilation techniques, and other climate management strategies by Rohit

Sonowal et.al[4]. In this paper, Nepali vernacular architecture and its structural components are examined, and the qualitative application of bioclimatic design principles is examined by Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

III. CONSTRUCTION TECHNIQUE

A. Hilly Region of India

Topographical Data is the detailed study of geological maps which identify geomorphological features, past and present land use. Site Reconnaissance is the initial part of site investigation which confirms the detail information through the topographic data, also about the site. Site investigation is conducted which is a practice of drilling and geophysical surveys. Soil sample is also taken from the boreholes of the site to conduct laboratory tests for the requirement of the rock and soil parameters, also the ground water in sensitive and critical areas. Check for slope and rock structure. For the construction of flat surfaces, stilts, sloping roofs, retaining walls, and storeys no higher than 3.2 m, the cut and fill technique is used. Because the inner portion of the cut slope may have a high carrying capacity and because platforms can be designed to meet natural counterslopes, south-facing slopes are favoured. Chawhan, Vrushali, and Mohammad ArifKamal[1]

B. Himachal Pradesh

1) *Zone 1 (Foothill/ Lower region)*: Mostly stone slabs are used for flooring and roofing, stones and mud are used to construct walls and wooden plank used to support intermediate floors commonly refer as floorboards which are supported by wooden joists and the slope of a roof is measured from its pitch which is limited to max 22.5 degree. Mud Construction house uses sun dried mud bricks, mud phuska plaster and wood plastered with mud for flooring. Dry stone construction is common where slate is in abundance. Stone slate used for roof with mud plastered on interior surface and the walls which evenly distributes the load in both orthogonal directions. Sharma, Sandeep and PuneetSharma[2]

2) *Zone 2 (Medium / Mid hills)*: Dhajji Wall Construction - Timber (wooden) frame is a traditional building method where large wooden beams are used to create the structural frame and stones are used to filled in the space between the wooden beams whereas brick masonry where the bricks are laid one on top of others with mud mortar applied in between and wooden used for flooring. In wooden-construction a vertical wooden posts which carry the load and horizontally placed with wooden battens. Upper floors are wooden cantilevers and stone masonry on ground floor. Sharma, Sandeep and PuneetSharma[2]

3) *Zone 3 (High mountain/The higher)*: Mud construction - Thick walls up to 0.60 m by pouring and mixing wet mud mortar and ramming before pouring it to another layer. Dry

stone construction: Different stone sizes are placed over each other and compacted without mud plaster or any mortar. Inner parts of house which is in interior surface are mud plastered. Sharma, Sandeep and PuneetSharma[2]

4) *Kullu Region (Himachal Pradesh)*: Dry Stone Construction (refer zone1), Dhajji-Dewari Construction and Wooden construction (refer zone2), Kath-Kunni construction is a technique of alternating layers of wood and stone masonry, held in place without using mortar. Panwar, Manoj, and Sandeep Sharma[3]

C. Nepal Region

1) *Sub-tropical climate*: Hipped and Pitched roofs, facade of the house faced towards North and South (longitudinal axis east-west) in-order to decrease the solar heat which absorb during hot season, mud layer floor, high ceiling. The external wall of the home's upper floor is constructed of loose bamboo strips and foundation (Earth/stone plinth or raised platform). Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

2) *Warm temperature*: Gable roof, pitched roof, saddle back roof, stone slates or thatch on timber structure. Wooden structure built with lath-work and mud plaster. The ceilings are very low and the openings are of medium size faced towards valley side. Small wooden windows faced towards south wards facade. Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

3) *Cold temperature*: Stonework that hasn't been plastered with mud plaster. Pitched roof, wooden pillars and beams, and thick stone roof slabs. Wooden lath-work and wooden flooring with carpet, small wooden windows placed only towards entrance side and one big living room window faced southwards with low ceiling. Some homes have a longer facade that faces the sun to increase solar gain. Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

4) *Alpine temperature*: South-facing house with brick walls on the upper floors and stone and mortar walls on the ground floor. Natural stone flattened for building and covered in white and red mud. Mostly flat roof with severe mud filling over wooden structure make it thick layer on roof. Low ceilings and small wooden windows. Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

D. Assam Region

1) *Lower Assam*: Wooden frame, slope roof, platform 30cm above the ground, verandas use a vertical wooden structure. Rohit Sonowal et.al[4]

2) *Upper Assam*: Bamboo sandwiched between two layers of mud. House face towards east-west and south for sunlight. Platform 30cm above the ground . Rohit Sonowal et.al[4]

E. *Churachandpur (Manipur)*: Air flow, light and shade through a porous, interior and exterior spaces ensures good ventilation allows the sun to all parts of the house. Rohit Sonowal et.al[4]

IV. SPACE DIVISION

E. *Hilly Region of India*: Rectangular, square, circular shapes and also building forms with expansion joints are preferred for the safety from the earthquake and open interactive spaces. Chawhan, Vrushali, and Mohammad ArifKamal[1]

F. *Himachal Pradesh*

1) *Zone 1 (Foothill/ Lower region)*: Two or more storey, steeply-sloping roofs, deep veranda. Sharma, Sandeep and PuneetSharma[2]

2) *Zone 2 (Medium / Mid hills)*: Cattle are placed on the first floor of a two-story building, and grains are placed on the second. The majority of homes are upper-floor structures with many uses for their verandas. Sharma, Sandeep and PuneetSharma[2]

3) *Zone 3 (High mountain/The higher)*: 2 -3 storey with lower storey used for the cattle's and upper storey for family. Openings which are windows and doors are generally of small size. Sharma, Sandeep and PuneetSharma[2]

4) *Kullu Region (Himachal Pradesh)*: Pitched roof. Kitchen located in inner core, ground floor use as livestock and storage, first floor habitable rooms, balconies and lofts. Panwar, Manoj, and Sandeep Sharma[3]

G. *Nepal Region*

1) *Sub-tropical climate*: Rectangular floor plan, single floor or more. 1st floor includes open veranda, and ground floor open courtyard, mezzanine used as storage. Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

2) *Warm temperature*: 2 or 3 Storeys in rectangular plan house with interconnecting courtyards or terrace. The ground floor made as kitchen and living space, first floor kept for sleeping and storage area. In vertically use of space has courtyard, the ground floor used as storage room, first floor for bedrooms, second floor as living room and third floor used as kitchen . Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

3) *Cold temperature*: Houses are attached in small groups along the slope hills with the shape of rectangular or L-shape of houses. Facades are faced towards south-west. Mostly it has 2 storey with ground floor as living area , kitchen and bedroom, first floor for storeroom area. Balcony and Veranda are also built as semi open area. Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

4) *Alpine temperature*: Square and rectangle floor plan with 2 or 3 storey with courtyard and roof terrace. Ground

level and upper floors are typically designated for secondary usage. Living area on the first floor. Ground floor are used for animals or cattle's. Rooms on the second level that serve secondary purposes, such as storage, etc. Additionally, the upper floor has a space for prayer or, during the summer, a place to sleep. Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

H. *Assam Region*

1) *Lower Assam*: In order to avoid flooding during times of severe rain, entrances are typically moved inside. For stability and durability, the first story is entirely made of wood, and the ground floor is made of brick masonry. Rohit Sonowal et.al[4]

2) *Upper Assam*: Veranda, dining in ground floor, dwelling in upper floor. Rohit Sonowal et.al[4]

E. *Churachandpur (Manipur)*: Living spaces are one-room (multi-function area) which assigned as dining or living space, bed or lounge, social gatherings and working areas such as cooking, weaving traditional shawls or bamboo cane. Veranda which are placed at the front (entrance) is a versatile work area. Rohit Sonowal et.al[4]

V. MATERIALS

A. *Hilly Region of India*: Light roofing material, gutters and purlins. Wood should be well seasoned. Timber, stone, slate, gravel ,mud, thatch, clay for brick and bamboo. Chawhan, Vrushali, and Mohammad ArifKamal[1]

B. *Himachal Pradesh*

1) *Zone 1 (Foothill/ Lower region)*: Rammed earth, stones, mud and wooden planks. Sharma, Sandeep and PuneetSharma[2]

2) *Zone 2 (Medium / Mid hills)*: Wood, stone, brick and mud. Sharma, Sandeep and PuneetSharma[2]

3) *Zone 3 (High mountain/The higher)*: Rammed earth, stones, mud and wooden planks. Sharma, Sandeep and PuneetSharma[2]

4) *Kullu Region (Himachal Pradesh)*: Stones, mud and wood. Panwar, Manoj, and Sandeep Sharma[3]

C. *Nepal Region*

1) *Sub-tropical climate*: Wattle and daub, straw and mud, timber, bamboo and thatch . Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

2) *Warm temperature*: Stone slate, mud plastered, burnt bricks, sun dried brick and wood . Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

3) *Cold temperature*: Stone, wood, mud mortar, stone slabs . Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

4) *Alpine temperature*: Stone and mud mortar, wood, sun-dried bricks . Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

D. Assam Region

1) *Lower Assam*: Bamboo, wood, cane, mud, lime , surkhi, thatched and baked bricks. Rohit Sonowal et.al[4]

2) *Upper Assam*: G.I.sheets, bamboo, wood, mud, lime. Rohit Sonowal et.al[4]

E. *Churachandpur (Manipur)*: Bamboo, thatch, lime and mud . Rohit Sonowal et.al[4]

VI. SUSTAINABLE FACTORS

A. *Hilly Region of India*: The majority of the building materials used in hilly areas are readily accessible, practical materials that are environmental friendly. which also brings minimal/ less disturbance to natural environment and contextual development and good climatic resistance. Chawhan, Vrushali, and Mohammad ArifKamal[1]

B. Himachal Pradesh

1) *Zone 1 (Foothill / Lower region)*: Local material which are environmental friendly and climate resistance. Sharma, Sandeep and PuneetSharma[2]

2) *Zone 2 (Medium / Mid hills)*: The material and construction of the vernacular house are economically and structurally stable. The structure of house which is frame of wood distributes the lateral loads if in case of any natural disaster such as earthquake. Sharma, Sandeep and PuneetSharma[2]

3) *Zone 3 (High mountain/The higher)*: Most of the house are built with local material. The earthquakes resistance of this vernacular house construction varies with the forms of and the type of loading on the walls. Sharma, Sandeep and PuneetSharma[2]

4) *Kullu Region (Himachal Pradesh)*: Local material which are environmental friendly ,climate resistance and resistant to seismic activities. Panwar, Manoj, and Sandeep Sharma[3]

C. Nepal Region

1) *Sub-tropical climate*: Local materials which are environmental friendly and climate responsive design . Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

2) *Warm temperature*: Warm temperate climates are very well fitted to the local climate of Nepal's region. Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

3) *Cold temperature*: In hilly region, the homes in Nepal's mild temperate environment are superbly tailored to the particular climatic circumstances.. Houses are built with local available materials which are environmental friendly and sustainable . Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

4) *Alpine temperature*: The houses are made of wood, which is heaped on the edge of the roofs to guard against high winds and rain. The natural climate in Nepal has greatly influenced vernacular house architecture. Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

D. Assam Region

1) *Lower Assam*: Local materials are resistant to seismic activities and it all respond to climate very well. Rohit Sonowal et.al[4]

2) *Upper Assam*: Houses have durability on the structure, rubbing the walls with same material mud mixture in certain intervals of time. Rohit Sonowal et.al[4]

E. *Churachandpur (Manipur)*: The local materials are environmental friendly and climate resistant. Rohit Sonowal et.al[4]

VII. THERMAL COMFORT

A. *Hilly Region of India*: Southern slopes are preferred due to higher bearing capacity inside the cut slope. In order to maximize the penetration of the sun rays, the orientation or the position of the houses are faced according to the sun direction. Chawhan, Vrushali, and Mohammad ArifKamal[1]

B. Himachal Pradesh

1) *Zone 1 (Foothill / Lower region)*: Wood plastered with mud enabling insulation. Sharma, Sandeep and PuneetSharma[2]

2) *Zone 2 (Medium / Mid hills)*: For the most part of the year, stone masonry and wood have a time lag of about 8 to 9 hours, which maintains the interior of the house warm and comfortable in the winter and cool in the summer. Sharma, Sandeep and PuneetSharma[2]

3) *Zone 3 (High mountain/The higher)*: Mostly the houses have thick flat mud roofs used for insulation and comfort. Energy is conserved by keeping room heights to 2.10 metres and having minimal apertures. Sharma, Sandeep and PuneetSharma[2]

4) *Kullu Region (Himachal Pradesh)*: The construction technique and the materials provides thermal insulation and thermal mass. Panwar, Manoj, and Sandeep Sharma[3]

C. Nepal Region

1) *Sub-tropical climate*: The long façade of the house faced towards the south side and the openings have medium size which penetrates air through the houses to provide cool

and comfort during hot and humid in summer months and gains solar heat during winter. Window shadings reduces the exposure to the sun . Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

2) *Warm temperature*: Buildings with courtyard designs receive solar penetration and provide warmer outside spaces for various home activities and obtain sufficient sun radiation via the windows to warm the space. The wall's thickness causes a large thermal mass. Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

3) *Cold temperature*: Mostly the houses on the ground floor as storage room provides thermal buffer space. Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

4) *Alpine temperature*: To maintain a stable climate, all of the dwellings are built with locally accessible insulation and have walls with a lot of thermal mass. Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

D. Assam Region

1) *Lower Assam*: Because the ground level is built of wood or bamboo and the ground floor is constructed of bricks, the ground humidity cannot enter the building. In ceiling design which provides air holes between 2 layers made from bamboo and wood which reduce heat build-up in the building. Rohit Sonowal et.al[4]

2) *Upper Assam*: Low thermal conductivity, high emissivity thatched provides insulation. Low thermal conductor porous bamboo floors and walls reduce condensation. Rohit Sonowal et.al[4]

E. Churachandpur (Manipur): Low thermal conductivity, controlled radiations from sun . Rohit Sonowal et.al[4]

VIII. DESIGN ANALYSIS

I. *Hilly Region of India*: Rectangular, square, circular shapes are preferred in order to avoid severe damage during earthquake. The materials are locally available within the region which is climate responsive design. slopping roof is design in order to drain off the rain quickly. Timber, mud and stone which provides thermal comfort during night or winter season . Chawhan, Vrushali, and Mohammad ArifKamal[1]

J. Himachal Pradesh

1) *Zone 1 (Foot hill/ Lower region)*: Walls made of sun dried bricks, thick plastered with mud pluska keeps the inner house warm. Wood flooring within the house are plastered with mud to act as insulation. The slop roof is to drain off the rain water quickly. Every household has 2 or more storey in which the ground floor are for cattle's providing heat to the upper floors. Sharma, Sandeep and PuneetSharma[2]

2) *Zone 2 (Medium / Mid hills)*: The snowfall, chilly winter, and excessive rainfall in this area had an impact on the building construction method. Stone and wood are the only available building materials, and they are used to construct the majority of better-class homes as well as some lower-class ones without the use of mortar. The extension of the upper floor is a common element of this region's vernacular architecture. Stone and wood are used to build the walls without the need of mortar, which promotes thermal comfort. Sharma, Sandeep and PuneetSharma[2]

3) *Zone 3 (High mountain/The higher)*: The development of vernacular architecture is dependent on construction methods because of the climate in the hilly area. Due to the extreme temperature difference between day and night, the rocks keep crumbling. Rammed earth block which is used for walls beaten earth for flooring provides thermal comfort and the thick flat mud roof consisting earth layer over 6-7 layers are for insulation. In order to save energy, rooms can only be 2.10 m tall, and there are very few openings. Because there was no alternative roofing material available, this method developed. Stone and wood is not available. Sharma, Sandeep and PuneetSharma[2]

4) *Kullu Region (Himachal Pradesh)*: The majority of homes in the Kullu region have passive architecture features that are used to control temperature and ventilation. The kitchen is typically located inside the building to keep the surrounding areas a little warmer. Additionally, because the ground floor is typically used for storing livestock and fodder, the first-floor living quarters are exposed to heat produced by the livestock. Panwar, Manoj, and Sandeep Sharma[3]

K. Nepal Region

1) *Sub-tropical climate*: Because of the prevalent tropical monsoon environment, houses are constructed to provide protection from the heat and heavy rainfall, therefore even the apertures (windows and doors) are of a medium size (20–40% of the outside wall area). Thermal comfort is provided by high thermal mass and high ventilation, especially during the hot and dry summer months. However, for the hot and muggy monsoon season, light building materials like thatch, straw, bamboo and wood are advised. Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

2) *Warm temperature*: Temperature; Warm Because the winter temperatures in Nepal's region are not particularly low, buildings there are constructed with their longer facades facing south and with medium-sized openings. This allows solar penetration of the south facade to provide solar heat gains in winter (when the sun angle is low) and reduce overheating in summer. Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

3) *Cold temperature*: Due to Nepal's cool, temperate climate and its high solar radiation in the winter, which is combined

with thermal mass (heavy walls and floors with a thermal time-lag of more than 8 hours), solar passive heating combined with thermal mass can significantly reduce the need for conventional heating. The windows and doors are kept as medium sized and the house are design to protect from heavy rains so proper rainwater drainage are made. Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

4) *Alpine temperature* : Temperature in the much colder and dryer alpine climate of Nepal. In order to improve the solar passive heating impact for big temperature swings between day and night, a compact building layout with small openings (15–25% of the outer wall area) and strong exterior and interior walls that are climate-responsive design are constructed. If the building's thermal mass can retain enough heat that is acquired from solar radiation throughout the day through the brick and mud, comfort can be reached in summer nights. The materials are locally available within the region in which it is built in climate responsive design. Bodach, Susanne, Werner Lang, and Johannes Hamhaber[5]

D. Assam Region

1) *Lower Assam*: Temperature in lower Assam region has a higher humidity and excessive rainfall during rainy season so in order to prevent flooding, a higher platform, about 30 cm above ground level, is constructed. Generally, the house has a wooden framed structure. The key benefits of wood include its hardness, moisture resistance, and low thermal conductivity. To prevent ground moisture, the base story is made entirely of brick masonry while the upper floor is entirely of wood. These building methods aid in maintaining a cooler or more comfortable interior temperature. Rohit Sonowal et.al[4]

2) *Upper Assam*: This part of Assam is humid and has a high rainfall so the houses are built according to the flood water level a higher platform, about 30 cm above ground level, is constructed in order to prevent flooding. Local available materials which are mud and bamboo helps cool down the inner space. Rohit Sonowal et.al[4]

E. Churachandpur (Manipur): This area in Manipur has a cold and humid climate. The vernacular habitants are one-room typologies which is used to fulfil multiple functions. The houses materials used were built only from locally available materials which gain thermal comfort for the habitant through all climatic changes. Rohit Sonowal et.al[4]

TABLE -1

Comparative analysis	TABLES
	Refer appendix at the end

IX. CONCLUSION

This paper identified different construction techniques for a vernacular house and its locally available material which are climate responsive design and subsequently are environmentally friendly and sustainable. In the hilly region of India, there are different construction techniques but almost use similar materials such as wood, stone, bamboo and mud. Mostly all the vernacular houses have adequate sloping roof, semi-open areas, shadings and protections from heavy rainfall. Thermal mass helps thermal insulation on the wood or mud floor, walls and roof during cold weather. In hilly regions, the houses structure must be thoroughly studied and understood in order to build in such type of topography. The typical climatic conditions, the landscape and the availability of raw materials are crucial for the construction of houses in mountainous regions which provides comfort and safe home to the region habitant. This paper reviewed on the different types of design, construction technique, layout and material in different mountainous regions of India with special reference to the seismic zone. These traditional vernacular houses contribute greatly to sustainability and lead to an approach of green building design.

FUTURE SCOPE

Since vernacular practised have been shown to be sustainable, it is crucial to learn from them when developing new projects and establishing building codes in order to achieve contextually appropriate and sustainable development in hill region. Bio-climatic architecture is an approach to building design that takes into account the local climate and uses natural resources, such as solar energy, wind, and water, to create comfortable and sustainable living spaces. Designing vernacular house according to the climate condition provides comfort inside the house throughout the season. It is also practicing in preserving and conserving the traditional architecture and interior design of the vernacular house.

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S. No.	Region	Climate	Temperature	Sea Level	Space Division	Construction techniques	Materials	Sustainable Factors	Thermal Comfort	Design Analysis
1	Hilly Region of India	Tropical monsoon climate, tropical wet	20°C to 31°C 24°C-4°C	800m-3500m	Rectangular, square, circular shapes are preferred and open interactive spaces	Topographical Data: Detailed study of geological maps, identify geomorphological features, past & present landuse. Site Reconnaissance: Helps confirm the information from the topographic data & about the site. Site Investigation: Drilling and geophysical surveys is a practice. Soil sample taken from the boreholes to conduct laboratory tests for the required soil & rock parameters. Also the groundwater is sensitive & critical areas. Check for slope and rock structure. Cut and fill, slope protection, retaining wall and height of tower not exceed 3.2m. South facing slopes are preferred since the kind of soil slope may have a higher bearing capacity. Designing platform to fix natural contour	*Light roofing materials *Gates and porches *Wood should be well seasoned *Tender, green, gravel, mud, brick, clay for brick and bamboo	Locally available, easily available materials which are environmental friendly which bring minimal disturbance to natural environment and construction development and good climatic resistance	Southern slopes are preferred. The orientation of the house is to maximize the penetration of the sun rays.	Rectangular, square, circular shapes are preferred in order to avoid any damage during earthquake. The material is locally available within the region which is climate responsive design. Sloping roof is design in order to drain off the rain quickly. Timber, mud and stone which provides thermal comfort during night or winter season.
2	Himal Pradesh	Zone-1 Foothill Low or region - subtropical climate summer, mid-winter (American rainfall)	0°C - 11°C	150m - 410m	2 or more storeys, steeply-sloping roofs, deep verandahs	Mass walls for flooring & roofing, stone & brick for walls & wooden plank supports or wooden joins for intermediate floors, the slope of roof is confined to maximum 22.5 degree. Mid Construction: The dried and kiln-dried planks plane, wood planked with mud on floor. Dry stone construction: Stone are roof/planked, orthogonal direction.	Random earth, stone, mud, wooden planks	Local material which are environmental friendly and climate resistant.	Wood planked with mud existing insulation	walls made of rammed brick, thick planked with mud & planks keeps the lower house warm. The floor made of wood planked with mud which provide insulation inside the house. The sloping roof is to drain off the rain water quickly. Every house has 2 or more storeys in which the ground floor is for cattle providing best to the upper floor.
		Zone-2 Medium and hills (summer, heavy rainfall & overcast in winter)	18.4°C mid temperature	451m - 1800m	2 or more storeys, built in the ground floor, grass in the middle floor, dwelling in upper floor and verandah for various purposes.	Thick Wall Construction Timber frame filled up with stone, brick masonry built in mud mortar, wooden floor. Wooden construction vertical wooden post carry the load, horizontal placed in 5% of wooden frames. Upper floors are wooden constructed and stone masonry on ground floor.	Wood, stone, brick and mud	Economical and structurally stable, Stone of wood distribute the lateral loads in case of an earthquake.	Stone masonry and timber has a time lag of 8-9 hours which keeps the house warm in winter and cool in summer for maximum part of the year.	Design of buildings in this zone is influenced by the climate of zone 1, it is dry winter & heavy rain fall. The building materials available are stone & woods which most of the better class houses & even poor one built with stone & wood, without mortar. The typical features of vernacular architecture in this zone is projected upper floor. With construction is done with stone and wood without mortar which provide thermal comfort.
		Zone-3 High mountains (The higher (Gairchi and north))	Humid temperature	1811m - 2200m	2-3 storeys, lower storeys used for cattle and the upper storey for family. Openings are generally of small size.	Mid Construction Thick walls upto 1.60 m by pouring wet mud mortar and ramming it before pouring another layer. Dry stone construction. Different conditions are placed over each other and compared with the mortar. Interior surface are mud planked.	Random earth, stone, mud, wooden planks	Local material. Earthquake resistance of this construction varies with the direction of the building the type of building the walls.	Thick fire walls are used for insulation. To conserve energy the height of rooms are confined to 2.10 m and openings are very small.	Due to climatic conditions the development of vernacular architecture is based on construction techniques. The rocks keep on disintegrating due to vast temperature difference between day & night. Random earth blocks which used for walls between earth for flooring provides thermal comfort. It thick fire wall and mud covering earth layer over 8-9 layers are for resistance. To conserve energy the height of rooms are confined to 2.10 m & openings are very small. This technique has been evolved due to absence of any other material available for roofing. Stone & wood is not available.
3	Assam	Warm and humid	32°C - 8°C	79.5 m	Lower Assam Earthquake are pulled inside to prevent the rain water. First floor is completely of wood and ground floor made of brick masonry.	wooden frame, slope roof, platform 30cm above the ground, verandah use a vertical wooden structure.	Bamboo, wood, cane, straw, brick, mud, plastered and brick.	Local materials are resistant to seismic activities and all responds climate very well.	Wood is resistant to moisture and has poor thermal conductivity. At lower which reduce heat build up in the building.	The zone has a high humidity & excessive rainfall so a higher platform about 30cm high from the ground level is built in order to avoid flood. Generally, the houses has a wooden framed structure. The main advantage of wood is it is hard, resistant to moisture & has poor thermal conductivity. At lower which reduce heat build up in the building. The first floor is made completely of wood & ground floor is made of brick masonry to make the structure free from dampness of ground. These techniques used in construction helps in keeping the temperature inside the house cool or more comfortable.
		Humid and high rainfall	10°C - 22°C	79.5 m	Upper Assam verandah, dining in ground floor, dwelling in upper floor.	Bamboo sandwiched between two layers of mud. House face towards east-west and north for sunlight. Platform 30cm above the ground.	Clay, stone, bamboo, wood, mud, lime.	Durability of the structure, nibbing wall with some mud mortar in certain intervals.	High emissivity thatched provide insulation. Low thermal conductance porous bamboo floor with mud plaster.	This part of Assam is humid and high rainfall so a higher platform about 30cm high from the ground level is built. Local available material which are mud and bamboo helps to avoid the lower space.
4	Charar Bassa - Jammu	Cold and humid	30.3°C	110 m - 1015m	Living spaces are one-room (multi family) are used for living, bed, lounge, social gathering & working areas for cooking, weaving or handicraft. Verandah in front is a veritable work area.	An open, light and airy through a porch, interior and exterior spaces are well ventilated. Allow the sun to all parts of the house.	Bamboo, thatch, lime and mud	Local material which are environmental friendly and climate resistance.	Low thermal conductivity, controlled radiation from sun.	This area has cold and humid climate. The vernacular habit are one-room typology which is used to fulfill multiple function. The materials used are again the locally available material which give thermal comfort for the habitant through all climatic change.
5	Kullu Region (Himal Pradesh)	Summer, Rainy and Winter	Max 33.8°C 14°C Min 16°C-2°C	2550 m	Kitchen located in more open, ground floor use as livestock and storage, first floor habitable rooms, balconies and late, pitched roof.	1. Dry Stone Construction, 2. Ditch-Drain Construction, 3. Wood construction, 4. Kath-Kamal construction - projecting layer of wood and stone masonry, held in place with mud mortar.	Stone, mud and wood	Local material which are environmental friendly and climate resistance and resistant to seismic activities.	Provides thermal insulation and thermal mass.	The majority of houses in the region have passive architecture features used for controlling temperature and ventilation in which the kitchen is preferably kept in internal core of the building to keep the surrounding space little warm, ground floor is generally used for livestock and fodder storage which exposed the habitable spaces on the first floor to heat generated from the livestock.
6	Nepal Region	Sub-tropical climate	17°C - 70°C	min 94 m - max 8940m	Rectangular floor plan, single floor or more, first floor includes open verandah, and ground floor open courtyard, verandah used as storage.	Hipped and Pitched roof, facade north-south and east-west, mud layer floor, high ceiling. Upper part of exterior wall is made of stone bamboo compo, foundation (earth masonry both or mixed platform).	Walls and dark stone and mud, timber, bamboo, thatch	Local material which are environmental friendly and climate responsive design.	Penetration of air through the houses to provide comfort during hot and humid summer months, reduce the exposure to the sun.	Due to the dominating tropical monsoon climate houses have to protect from heat & heavy rainfall so the openings (windows & doors) are of medium size (20-40% of one wall area). High thermal mass with night ventilation which provide thermal comfort, particularly during hot & dry summer period. However, light building use with which are thatch, stone, bamboo & timber are recommended for hot & humid monsoon season.
		Warm temperature above 3000 m level	10°C - 10°C	min 94 m - max 8940m	2 or 3 storeys, Rectangular plan with an open courtyard, courtyard or verandah. Ground floor kitchen & living, 1st floor sleeping storage. Vertical use of space, ground floor storage, 1st floor bedroom, 2nd floor living room, 3rd floor kitchen, courtyard.	Hipped and Pitched roof, saddleback roof, Madhank covered. Wooden structure with lattice work and mud. Medium sized openings toward valley side. Small wooden windows concentrated facade, ceiling are very low.	Stone, slate, and plaster, thatch, brick, mud, wood, brick and wood.	Nepal's warm response designs are very well adapted to the local climate conditions. Local available material which are environmental friendly.	Courtyard design allow solar penetration to building & provide warmer outside space for all kind of household activities & reduce enough to be radiated through windows to heat up the room. The thickness of the wall limits high thermal mass.	Temperature in Nepal's warm temperate climate does not drop down drastically during winter so the buildings are built oriented with the larger facade toward south and have medium sized openings, by this way solar penetration of the south facade prevent solar heat gain in winter (when the sun angle is low) and reduce overheating in summer.
		Cold Temperature	5°C - 20°C	min 94 m - max 8940m	Attached houses in small groups along the slope, rectangular or L-shape facade towards south-west.	Upland and stone or plaster, mud mortar. Pitched roof, Wooden pile and beam structure with heavy stone slab, Wooden lattice work, wooden floor with carpet. Low ceiling, small wooden windows only in entry facade, one large living room window facing southward.	Stone, wood, mud mortar, stone slabs.	The mountain houses in the cool temperate climate of Nepal are very well adapted to the local climate conditions. Local available material which are environmental friendly.	Ground floor as thermal buffer space.	In cool temperate climate the use of solar radiance for passive heating is an effective design strategy during the larger winter, due to high solar radiation in winter solar passive heating combined with thermal mass (heavy walls and floors with thermal time-lag of more than 1h) can reduce the need for conventional heating considerably. The windows and doors are kept as medium sized and the houses are design to protect from heavy rains in proper rainwater drainage are made.
		Alpine temperature	0°C - 11°C	min 94 m - max 8940m	Space & rectangle floor plan. 2 or 3 storeys, Courtyard, roof terrace ground & top floor are equipped to receive any sun. Living area in 1st floor. Animals are housed in ground floor 2nd floor surrounded by rooms/secondary use like storage etc. upper floor, prayer room or a sleeping room for visitors.	Thin, gable, Lower wall, stone and mortar, upper walls mud-brick. Flat natural stone masonry covered with white and red mud. Stone roof. Mid filling masonry ovoid with stone structures on roof. Low ceiling, small wooden windows.	Stone and mud mortar, wood, mud-brick, bricks.	Stone piled on the lower of roofs that provide protection from the strong wind. Vernacular house design is very much adapted to the local climate conditions.	All are constructed with insulating material locally available and have walls of high thermal mass to balance the climate.	Nepal's alpine climate is the coldest and drier. Therefore, compact building layout and small openings (15-25% of outer wall area) are built and heavy external and internal walls which are climate-responsive design to reduce solar passive heating effect for large temperature which bring between day and night in summer nights comfort can be achieved if the building's thermal mass can store enough heat that is gained from solar radiation during the day through the brick and mud. The material are locally available within the region in which it is built in climate responsive design.