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VERNACULAR PRACTICES: AN APPRAISAL FOR SUSTAINABILITY FOR HOUSING IN UTTARAKHAND AND HIMACHAL PRADESH, INDIA

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ABSTRACT

Quality of environment is the basic requirement to achieve sustainable development. The problem of degrading environmental conditions and increasing pressure on land due to the numerous multi-storeyed buildings constructed using contemporary materials and techniques in hill settlements has become a critical concern in India. These settlements are undergoing rapid urbanization and are witnessing environment degradation in the form of climate change, ecological change, loss of vegetation cover, natural drainage pattern change, increase in surface runoff, reduction in recharging of the water table, increase in slope failures, increase in soil erosion and pollution which not only affects the town but also the surrounding regions, the urban environment, the development patterns, existing buildings, open spaces, and infrastructures. Despite the advantages of vernacular practices, they are often not applied in contemporary development. The increasing demand for more space due to population growth and rapid development in construction practices has resulted in the extinction of these architectural practices and hence questions the sustainability of these settlements. This paper explores the vernacular practices of Uttarakhand and Himachal Pradesh, focusing on the traditional knowledge of materials, construction techniques, community involvement, and settlement planning. The significant features in these regions like, structural detailing and materials used in Koti Banal, Kath-Kuni, Mud Wall Structures, and Dry-Stone Structures are considered for the study. Further, there is an investigation of the modifications that have happened over the years in these practices with respect to morphology and materials through a case study of Kumaon and Garhwal regions in Uttarakhand, and, Shimla and Hamirpur in Himachal Pradesh. The paper draws an inference on the existing vernacular practices and modifications required for better planning and designing of settlements at settlement level, cluster level, and site-level that will promote vernacular practices and environmentally friendly development of ecologically fragile hill towns.

KEYWORDS: *Construction Techniques, Environment, Hill Settlement, Sustainable Development, Vernacular Practices*

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INTRODUCTION

The Himalayan regions of North India are known for their numerous vernacular practices and styles of architecture that was developed during the past centuries to meet the requirements of the people. These vernacular practices are developed by the people, for the people, without any technical/professional training; with the help of locally available, natural and environmentally friendly construction materials and indigenous construction techniques which people learned, developed,

and refined over centuries (Kumar and Munoth, 2011). These construction techniques were mainly influenced by the climatic factors such as solar exposure, wind movement, amount of snowfall and rainfall, etc. but also considered the topography of the region. Despite their positive environmental effects, these practices have a number of disadvantages, including the need for frequent maintenance, low strength of materials or building components, a lack of skilled craftsmen, a scarcity of traditional materials, and residents' reluctance to adopt vernacular practices, which has resulted in a decline in the use of these sustainable practices for the construction of buildings in hilly areas.(Kumar and Pushplata, 2013).

The need of rapid development, increased urbanization, better transport facilities and need for high-rise structure promoted the use of contemporary materials like concrete, which are alien to the region. But the society keeps on demanding improved services, fast and easy modes of construction to meet the needs of its inhabitants which in turn caused a severe damage to the fragile environment in and around the settlements. To minimize the impact of the damages caused by the contemporary techniques on the environment, the use of vernacular practices needs to be revived.

As per Laurie Baker, Every place has its own traditions, and people have learned how to use and cope with all of the factors involved in Architecture through trial and error over thousands of years that is he site, topography and geology, environment and vegetation, accessible local materials, religious and cultural patterns of living, and the key local inhabitants. Unsatisfactory products have been discarded for a long time, and substitutes have been sought before a suitable solution is found. As a result, abandoning the tried and true results of centuries of science and technology seems foolish.

STUDY FRAME AND METHODOLOGY

The methods employed for the research of this paper includes the following steps: -

- Information and understanding on various types of vernacular practices, which includes Koti Banal (Uttarakhand), Kath-Kuni (Himachal Pradesh), Mud Wall Structures (Himachal Pradesh), and Dry-Stone Structures (Uttarakhand and Himachal Pradesh), gathered not only from the previous researcher-literature but also a primary study made by the authors during the months of January and February 2021.
- A conceptual framework will emphasize on the interrelationships between – vernacular style, knowledge of material, construction techniques, community involvement and settlement planning.
- Detailed case study done previously by known researchers will be studied in the selected areas of Garhwal and Kumaon region in Uttarakhand and Shimla and Hamirpur region in Himachal Pradesh.
- A study has been conducted by recognition survey, land use identification and drawing the specific use spaces in relation to functional activity, materials, vernacular construction techniques and their attachment image/character were analyzed and inferences were drawn. The data collection was through questionnaire, unstructured interviews along with photographic study and on the spot sketches during the months of January and February 2021.

Conceptual Framework

The four major aspects that go into formulation of conceptual framework are: -

- Indigenous knowledge of materials acts as creating a unique identity. Studying the role of materials and the native science of building will be one important aspect. Both the states have developed their own unique architectural styles with the use of local materials.

- The vernacular nature of construction and techniques incorporated play an important role in identifying the style relation with the region and its surrounding. The transition from vernacular to contemporary style, and use of materials like concrete, brick and other new materials have reduced the value of vernacular practice, which should be preserved and celebrated.
- The role of community and the methods followed by them to create the settlement and livelihood plays a major role in studying the architecture of any place. The elements of community will also play a role in the endurance of vernacular landscapes and will be the key to understand their culture and society. Since, the implications of vernacular practices have reduced over time, the questions about them can only be answered by the local masons and workers of the community.
- With time, the traditions and culture have been modified. Similarly, the pattern of settlement has also changed, which now becomes an important part of the study. Growth of the settlement in selected areas to the future scopes of development in these areas can be determined by the society and the sustained practices of the region.

SUSTAINABLE PRACTICES OF UTTARAKHAND AND HIMACHAL PRADESH

In the hilly region, local construction work force is using modern materials in their construction without technical knowledge of reinforcement, curing, structural stability of frame structures and load transfers (Fazil and Agarwal, 2011). It is important to develop a strategic approach and detailed analysis to identify the strengths and weaknesses of vernacular practices and contemporary practices for a long-term development of the built environment which is sustainable and environmentally friendly. Here the local people have developed several vernacular practices for creating a better built environment for themselves, without any formal training of construction techniques and knowledge of material, but have proven to be resistant against harsh climate by using local natural raw materials and evolving by studying the nature itself (Sadhu and Ramesh 2020).

Koti Banal / Kaath Kuni Style

Koti Banal in Uttarakhand and Kaath Kuni in Himachal Pradesh, is one of the oldest architectural style followed in the Himalayan region. It is found that, this architectural style had evolved in the region as early as 1000 years before present. These multi-storeyed houses are found with abundant use of wooden beams and stone bases. The buildings are constructed using the locally available building materials such as long thick wooden logs, stones, and slates (Saraswat and Mayuresh, 2017). The height of these structures varies between 7 to 12 metre above the base platform which consists of dry stones (Rahul and Ahuja, 2014). These structures are generally built till four or five floors and are found to withstand many of the major earthquakes in the region. This architectural style is one of the most suitable for construction in these regions if a suitable replacement can be found for timber as wood is scarce nowadays. This style proves to have the minimum environmental impact and maximum earthquake resistance (Rautela and Joshi, 2008).

Figure 1: Kath Kuni Style, Himachal Pradesh (Source: Kumar and Pushplata, 2013)

Figure 2: Koti Banal Style, Uttarakhand (Source: Saraswat and Mayuresh, 2017)

Dry Stone Construction

This type of construction style is found in the areas of Uttarakhand and Himachal Pradesh where the precipitation rate is high in terms of both rainfall and snowfall. This design is popular in areas where people have been forced to abandon their conventional building methods due to a lack of wood (Rahul and Ahuja, 2014). Thus, this construction style is similar to other traditional housing style omitting the wooden elements.

The walls made of stones are load bearing in nature with a thickness of 500mm and a height of 2.5m. Whole structure is constructed using undressed stones which are locally available. These stones of varying sizes are packed together without the use of mortar. Windows and doors are made up of deodar or Kail, locally available wood. Sloping roof system is used in these regions as they receive high amount of rainfall in monsoon and snowfall in winters. Roofs are covered with slate stone while deodar or Kail is used for making rafters and beams (Rahul and Ahuja, 2014). Dry stone houses response during earthquake is excellent and construction economics also favors it thus making it a viable option in the present day scenario.The heat capacity of different materials used in both the study areas have been analyzed and found that supply of water has become utmost important factor to store and use has become one of the important factor where it amounts to 4.2 J/g.K. Similarly for other materials such as brick, concrete and stone stood in the range of 0.8-0.9 J/g.K as analysed with reference to the thermal characteristics and properties of the materials. The thermal capacity of various materials used in their buildings calculated and found that the wood leads the entire list of materials brick, concrete, earth, gypsum and stone as shown in the table 2. The indoor comfort is achieved by the walls and roofing system and detail of its construction as elaborated in fig.5. The uniqueness of the wall system of integrating timber and stone and its details given in fig.5 where the thermal transmittance of U-value averaging to 0.1725 W/Hour degree C so as to retain the heat generated in the dwelling unit. By virtue of its roofing system of staggered local slabs with crack lengths facilitated to have four air changes through ex-filtration with reference to thermal buoyancy of displaced ventilation and density variation of the room air temperature through vertical temperature gradient from floor to the pitched roof ceiling the has been shown in stages of its construction in Fig.6.

Figure 3: Dry Stone Construction, Himachal Pradesh (Source: Rahul and Ahuja, 2014)

Figure 4: Dry Stone construction, Uttarakhand (Source: Kumar and Pushplata, 2013)

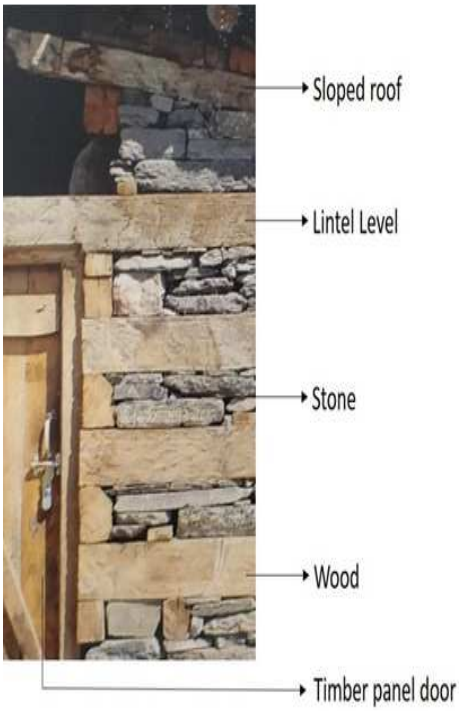

Figure 5: Figure Name (Source :SPAV, IIY, B.Arch Batch 2014-19 Study 2015)

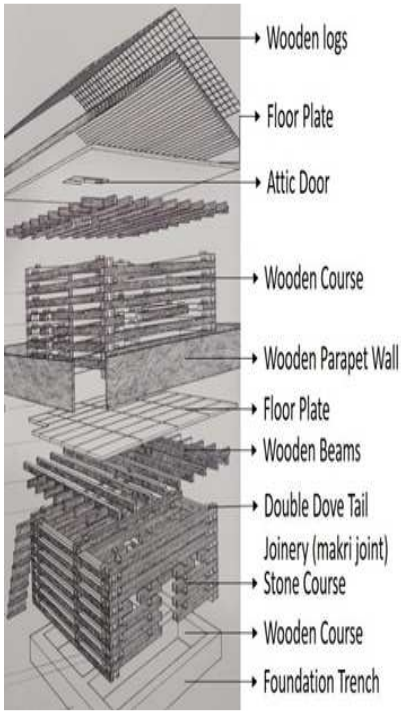

Figure 6: Figure Name (Source :SPAV, IIY, B.Arch Batch 2014-19 Study 2015)

Mud Wall Construction

Mud wall construction style is practiced in the cold desert areas of Himachal Pradesh. The change is temperature within the day affects the construction style of this place, the cold desert areas experience very hot days with chilling nights. Precipitation occurs in the form of snowfall with almost no to very little rainfall. Due to this, the dryness is reflected in the architectural style with thick mud walls and small openings, the interior is insulated from the outside harsh climate (Sarkar, 2013).The houses developed in these regions have a load bearing wall system with each wall dimension varying between 300mm to 500mm thickness. The main building material used is mud which is easily available with field stones being used to raise the level of house from the ground. The areas experiencing rainfall have sloping roof with slates covering them, while other regions have flat roofs, wooden beams covered plaster of mud over reed leaves (Rahul and Ahuja, 2014,' Dekit and Ramesh' 2019). The efficient way of construction by using mud, which is easily available locally and suits the harsh climate makes this style an efficient option for present day development.

The study of mud walls in both the regions revealed that the time lag of thermal conduction through walls and roofs from higher temperature to lower temperature has measured and found 8.25 hours as compared to 2.5 and 3.75 hours of brick and stone wall respectively. The decremental factor, diffusivity, time lag and thermal transmittance of locally available materials in these regions have been analyzed through standard formulas has given below and the results were shown in Table 2. The table 2 indicates that mud, timber and stone giving the suitable results in terms of its thermal behavior and the same has been identified in Himachal Pradesh and Uttarakhand study areas.

Figure 7: Mud Wall Construction with Sloping Roof (Source: Kumar and Pushplata, 2013)

Figure 8: Mud Wall Construction with Flat Roof (Source: Kumar and Pushplata, 2013)

CHARACTERISTICS OF VERNACULAR SETTLEMENTS IN UTTARAKHAND AND HIMACHAL PRADESH

Various characteristics of vernacular settlements for planning and designing of house in a hill region are

- The settlements are generally planned on relatively flatter terrain as compared to slopes in surrounding areas as they are considered more stable for construction purpose (Figure 9 and 10).
- The settlements are generally developed on southern slope for relatively more solar exposure and protection from northern winds, making the conditions suitable for living.
- Selection of site mainly depends on the proximity of the site to surface water source, as it is difficult to construct water structures (like well) due to the instability of ground water table.
- Planning and design of buildings depends on the type of settlements, which are broadly classified into three categories as ridge, mid land and valley settlements (Kumar and Pushplata, 2013). Temples, markets, schools, and public areas are designed in ridge settlements while open grounds are located in valley areas. Housing is located on sloped terrains.
- Contours play a major role in design as the buildings are constructed along them to reduce the site work.
- Housing buildings are located around an open ground/courtyard which is used by the residents for communal activities. Buildings are placed in such a way that no building cast its shadow on other building and each of them having a proper opening for ventilation and maximum solar exposure.
- The buildings in these settlements are generally rectangular in shape, constructed using local materials and techniques.

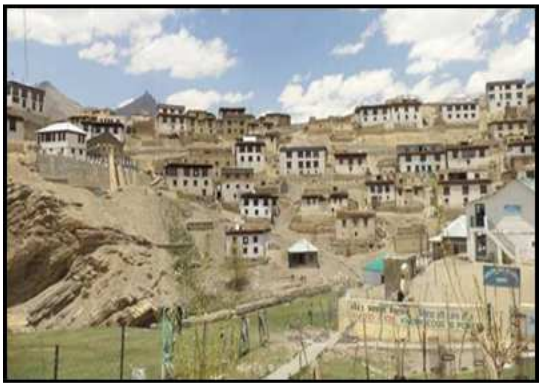

Figure 9: Settlement in Middle Himalayan Region (Source: Kumar and Pushplata, 2013)

Figure 10: Settlement in Upper Himalayan Region (Source: Kumar and Pushplata, 2013)

Table 1: Comparative Analysis of Different Vernacular Practices in Uttarakhand and Himachal Pradesh

S. No.	Characteristics	Koti Banal/Kaath Kuni	Dry Stone Style	Mud Wall Style
1	Materials	Stone and Timber	Undressed Stone	Mud and Earth
2	Areas	Northern part of Uttarakhand and Southern part of Himachal Pradesh	High precipitation areas of Uttarakhand and Himachal Pradesh	Low precipitation areas of Himachal Pradesh
3	Structure	Column and beam	Load bearing wall	Load bearing wall
4	Roof	Sloping roof with wooden rafters	Sloping roof with deodar or Kail rafters covered with slate stone	Sloping roof covered with slate stone. Flat roof covered with thatch and mud
5	Height	7- 12m (four to five storey)	2.5- 4m (single storey)	2.5- 7m (double storey)
6	Special Characteristics	Good seismic and thermal response, good aesthetic value	Good thermal response	Good seismic and thermal response

CONTEMPORARY CONSTRUCTION PRACTICES

With rapid urbanization and need for fast development, started the use of contemporary materials and techniques. The materials like concrete became one of the most readily available materials which have reduced the use of these traditional practices in India. The industrialization of cement production in the last 30 years has eroded traditional methods of building, local skills and local markets (Fazil and Agarwal, 2011). The use of such contemporary materials and techniques resulted in significant changes to the environment and surrounding, creating a risk and vulnerability for the local communities. The life span of these structures is estimated to be 50 to 80 years by its developer while the built environment created using the vernacular practices have withstood a much longer lifespan with minimum maintenance, and are much environmentally friendly than these modern practices.

Figure 11: Buildings Covering Entire Hill Slope in Shimla Town (Source: Ashwini Kumar, 2015)

CONSIDERATIONS FROM VERNACULAR PRACTICES FOR CONTEMPORARY CONSTRUCTION

Different learning from these vernacular practices of hill settlements can be used to formulate the consideration for planning and design of modern buildings, which can be categorized into three groups as, considerations at settlement level, cluster level, and site level.

Settlement Level

Different considerations for site selection as observed in vernacular practices can become the basis for site selection for modern buildings, such as site selected for development should be on the southern slope of the hill to have adequate amount of sunlight, should be on leeward side of hill to have protection from cold winds, should have access to basic amenities, should be developed on stable terrain to make them resistant against natural disasters like landslides and cloudburst.

Vernacular patterns of settlement can be formulated to develop the pattern for new development in different zones for hill settlement broadly classified as ridge, midland and valley settlements. Temples, markets, schools, and public areas are designed in ridge settlements while open grounds are located in valley areas. Housing is located on southern side of sloped terrains.

Traditional settlements on hilly areas merge well with nature and cause minimum damage to the environment. This can be the basis of deigning new buildings such that they merge with surroundings and cause minimum damage to environment to become the integral part of the nature. They should also be developed such that they are contextually appropriate as notices in different regions in India considering the climate, culture and occupation (ramesh 2015).

Figure 12: Traditional Settlements Merge Well with the Surroundings
(Source: Kumar and Pushplata, 2013)

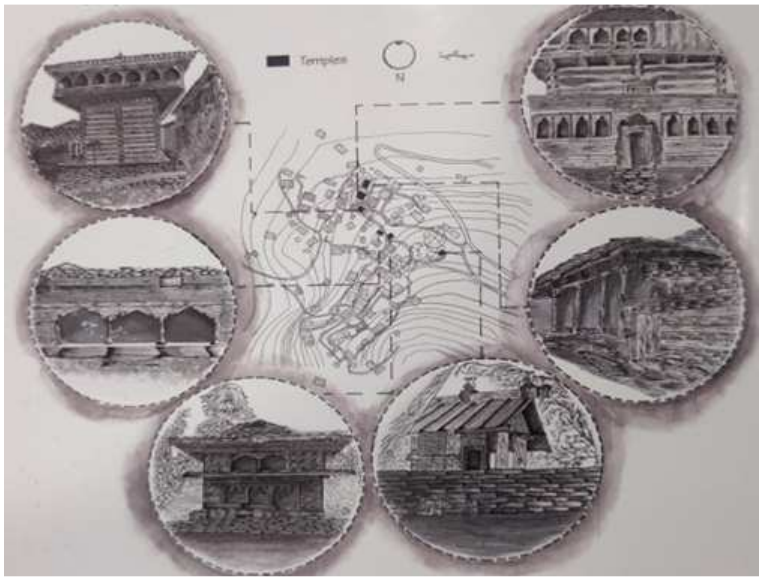

Figure 13: Types of Vernacular Built Form
(Source: SPAV, IIY, B.Arch Batch 2014-19 Study 2015)

Cluster Level

Different considerations for clustering of buildings can be considered from the vernacular practices such as, clustering of building should be done around open spaces where all the residents are able to use that open space for community interaction and social activities. The orientation of building and open spaces should be designed in such a way that the buildings have maximum solar exposure and minimum wind exposure. The placement and height of built structures should be decided in a way that they should not cast shadows on other buildings in the area.

Different settlements have different characteristics according to the community showcasing their own identity. The buildings may look similar to one another due to the use of similar kind of materials, but they are different in ways such as, spatial organization, size of structure, placement of rooms, facade elements, decoration and ornamentation. These principles can be adopted for development of new structures in different zones/settlements to show their unique identity and at the same time different settlements of different communities woven together to create a scenic beauty on hills.

Site Level

Vernacular buildings are generally developed along the contour to reduce the amount of site work. The same principle could be adopted for development of modern buildings minimizing the effect on the surrounding.

New buildings should adopt the feature of smaller footprints, similar to vernacular settlements. They should have openings on the longer side of the structures, while the shorter side is kept intact for better seismic response.

The buildings should merge well with the surroundings and should be developed using the locally available materials and techniques. This will make them unique in nature and will also blend in with the context of the community which is necessary for environmental protection (Sadhu and Ramesh 2019)

The methods adopted in constructing these buildings are known locally, so programs for training and knowledge of local material and techniques can be adopted which will not only increase the employment opportunity but will also help in protecting these practices for future generations such as rain water harvesting, daylighting utilization and courtyards for comfort conditions (Karteek and Ramesh 2017).

Figure 14: Rural Mud Wall House of Hamirpur, Himachal Pradesh (Source: Sarkar, 2013)

Figure 15: Housing Cluster of Khyah Village, Himachal Pradesh (Source: Sarkar, 2013)

The local materials used for dwellings have got the potentiality of withstanding the harsh environmental conditions and these vernacular dwellings are blends with nature and susceptible to climatic conditions to that context. Considering heat to be transferred from higher end to lower end through conduction, convection and radiation, from one side at temperature TA to the other at temperature, TB. Assuming steady state, i.e., the heat transfer rate, q per unit area of the structure is the same through the envelop as given below:

$$q = Ah_a(T_A - T_o) = AK_1\frac{T_o - T_1}{L_1} = A\frac{T_1 - T_2}{L_2}K_2 = A\frac{T_2 - T_3}{L_3}K_3 = Ah_b(T_3 - T_B) \quad (1)$$

where A is the surface area and terms like $h\Delta T$ represent heat transfer by both convection and radiation and the terms like $\frac{K}{L}\Delta T$ represent heat transfer by conduction through various layers.L1,L2 and L3 are the thickness of the layers of thermal conductivity, K1,K2 and K3 respectively and the interface temperatures.

Hence, the total thermal resistance (R) in the path of heat flow from temperature TA and TB is the sum of several different thermal resistances. And the overall heat transfer coefficient (U) which is characterized as the unit conductance of a composite layer, is related to the total thermal resistance R of the composite wall by

$$U = \frac{1}{R} \tag{2}$$

Such that,

$$R = \frac{1}{U} = \frac{1}{h_a} + \frac{L_1}{K_1} + \frac{L_2}{K_2} + \frac{L_3}{K_3} + \frac{1}{h_b} \tag{3}$$

The phase lag is the time delay between the impact of the diurnal variation of the temperature and radiation on the external surface, and the resultant temperature variation on the internal surface. The heat storing capacity of the building components, plays a crucial role in determining the phase lag bringing forth marked difference between the time dependent thermal performance of heavy weight and low weight structures under such circumstances. The time lag for homogeneous materials subject to the temperature fluctuations with a 24 hours period is given approximately by the formula:

$$\psi' = 1.38L\sqrt{\frac{1}{=}}_{v} \tag{4}$$

Where ψ' is the time lag(in seconds) L is the thickness(m) and ($\bar{v} = k/\rho c$) is the thermal diffusivity (m2/s). Since the resistance of one layer influences the rate of heat transfer to the neighboring layer, the thermal behavior of multi-layer constructions is more complicated. The time lag is calculated by the properties of the layers and the order in which they are organized, rather than the sum of the time lags of individual layers. The researchers emphasized that considerable savings in the material can be achieved by the judicious use of local indigenous materials with low heat capacity, and heavy insulating materials to retain high heat capacity to achieve long time lags without using extreme thickness with combination of timber and stone courses or with mad walls and thatched roofing (Ramesh et al (2020), Sodha et al. (1985)).

After heat is absorbed at the external surface, the effect of thermal ability in a building part is to delay the attainment of steady state conditions. The temperature shift at the exposed surface propagates through the material as a temperature wave, which gradually loses amplitude as it progresses. The temperature at any point will be sinusoidal with the same frequency as the change in temperature of the exposed surface, but it will lag behind the difference in the surface temperature [Sodha et.al, 1986, Ramesh et.al, 2019]. The amplitude decrement factor for a single layer wall can be determined using the following formula from the literature:

$$\mu = \exp\left(-L\sqrt{\frac{\omega\rho C}{2k}}\right) \tag{5}$$

Where,

$$\omega = \frac{2\pi}{(24.)(3600)}(s^{-1})$$

L is the thickness of the wall, k thermal conductivity (W/m0C); ρ the density (kg/m3),C the specific heat (J/kg K) of the building material.

The time lag through a multi-layered system can be measured using the time constant principle, which is defined as the time it takes for a layer of wall or roof to warm up as a result of an instantaneous shift in external temperature. It is defined by the ratio:

$$Time\,constant(\tau) = \frac{Volumetric\,heat.capacity\,of\,the.material\,layer}{Ratio\,of\,heat.transfer.in..to.material\,per.degree.temperature..difference} = \tau = \frac{Q_v}{U} \quad (6)$$

The materials used in these vernacular dwellings have been studied in relation to the thermal behavior to understand the potentiality and compared and same has shown in Table 2 and 3.

It is found that the local practices related to the vernacular techniques, components and materials show that the stone and mud walls are analyzed as per above expressions, yielded approximately 5 and 10 hrs of time lag with appropriate U-Value of thermal transmittance as shown in Table 2 and 3.

Table 2: Properties of Materials

Building Material	Thermal Conductivity	Density	Specific Heat	Width	Diffusivity 10^{-7}
	W/m^{o}C	kg/m^3	J/kg^{0}C	m	m^2/s
Concrete(1:2:4)	1.4	2100	800	0.15	8.3333
Lime concrete	0.969	1762	840	0.2	6.5469
Reinforced brick	0.7294	1920	800	0.2	4.7487
Brick	0.84	1700	800	0.23	6.1765
Granite stone	3.98	2640	820	0.38	0.18343
Sand stone	1.83	2160	710	0.38	0.11933
Mud	0.518	1922	1382	0.45	1.9502
Wood	0.159	721	126	0.2	0.175

Table 3: Properties of Materials

Building Material	Decrement Factor	Time Constant	Time Constant	Time Lag	Time Lag	Uw	Us
		hrs	hrs	hrs	hrs	W/sq.m^{o}C	w/sq.m^{o}C
Concrete (1:2:4)	0.2668	12.112	10.78	4.35	4.00	3.02	3.16
Lime concrete	0.2253	13.2831	12.11	4.66	4.35	2.53	2.63
Reinforced brick	0.1738	16.6777	15.46	5.55	5.23	2.16	2.23
Brick	0.2156	13.4029	12.32	4.69	4.41	2.35	2.43
Granite stone	0.4109	10.0613	8.34	4.81	4.36	2.19	2.47
Sand stone	0.3315	9.6266	8.41	5.70	5.38	1.86	2.04
Mud	0.0652	37.0973	34.99	10.89	10.34	1.74	1.79
Wood	0.4019	3.4687	3.40	2.09	2.07	0.69	0.70

CONCLUSIONS

The vernacular practices of a place are sustainable and better for environmental protection can be proven by the fact that they have lived in the context for centuries, they have developed and evolved according to the needs of people. The changes and moderation in the practices have taken place according to the climate, the culture and the social requirements of the community. These practices can form the basis for the development of modern buildings and in order to achieve sustainability in modern construction in hill settlements of Uttarakhand and Himachal Pradesh, these techniques need to be revived to help us in maintaining the ecological balance of the region and minimize the climatic change caused due to contemporary construction. Reviving these practices will also help the local culture to develop and will increase the

employment opportunity in the region resulting in economic growth of the region. Moreover, this will ensure that these practices maintain to be unique in character and to specific region. It is also true that these practices can't be adopted in their earlier form but with some modification in materials and techniques they still prove to be better solution and can be integrated with modern construction techniques.

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