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Adaptive Climate Responsive Vernacular Construction in High Altitude

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***Abstract*—**In the traditional architecture, buildings were designed to achieve human comfort by using locally available building materials and construction technology which were more responsive to their climatic and geographic condition. This paper will try to bring out the wisdom of the local masons and builders, often the inhabitants themselves, about their way of living, and shaping their built environment, indoor and outdoor spaces, as a response to the local climatic conditions, from the findings of a field-study at a hilly settlement.

***Keywords*—**Traditional architecture, High altitude, Climatic adaptation, Sustainable construction

I. Introduction

WITH the advancement achieved in the field of building science and technology, we are increasingly becoming aware of the importance of the energy-efficient building design[1]. Many a times one can find the solution to optimize the use of resources and to achieve the human comfort by critically evaluating the vernacular architecture of that place [2]. Inhabitants often employ and use various adaptive features in their houses to keep the indoor conditions within comfortable zone [3].The best way to understand the architectural characteristics of a settlement is by conducting field survey/study. During the physical on-site survey of the settlement, individual automatically starts gaining knowledge about the process of shaping their built-environment, evolution of the building typologies and their adaptation with change in their need [2, 4]. The following study was conducted to gain knowledge and wisdom from the local masons and builders, often the inhabitants themselves, about their way of living, and shaping their built environment, indoor and outdoor spaces, as a response to the local climatic conditions.

II. Objective of the Study

Following were the objectives of the study of a hill settlement:

- To find out the morphological growth pattern of the settlement,
- To understand the architectural planning pattern of the settlement,
- To analyze the architectural design of the individual dwelling units as manifestation of various design parameters, such as local climate conditions as well as the socio-economic-political situations of that time period, and
- To find out the architectural details of various building elements, motifs, symbols, etc., used by them to build our design vocabulary.

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III. Description of the Settlement

The aim was to find out the salient architectural features of a hill settlement. For that a traditional settlement in the hilly region of district Kullu at Himachal Pradesh was selected. The settlement was at the village Bhalyani, in district Kullu, situated in the Lug valley, having 31º56'N latitude & 77º2'E longitude, at an altitude of 1952Metres above mean sea level, about 9 km from district main city Kullu [9, 10]. Main seasons found in these regions are Summer - from March till June, Winter - from December to February and Monsoon - from July to September. During summer season, maximum temperature reaches to 33.8˚C and minimum of 14˚C. In winter, maximum temperature reaches to 16˚C and minimum of 2˚C. During the winter months, the temperature goes down to the freezing point, even heavy to medium snowfall occurs. Pleasant climate is found during the autumn season of October & November. This region also experiences rainfall during July to September, when the weather becomes chilly because of the proximity to the snow range. Therefore, the cold climatic conditions are predominant here, which is also supported by the climatic classification of India by the National building Code of India [7]. It will be seen that to provide comfort to the occupants from the cold conditions plays a major role in shaping the settlement structure and human habitat there. Fig. 1 shows the location of Bhalyani settlement at Kullu.

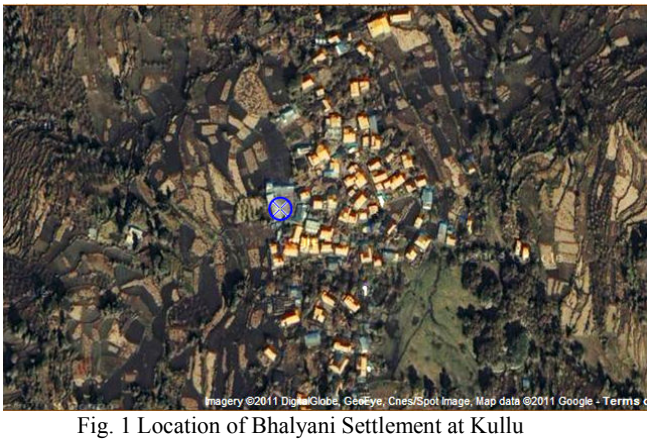

Fig. 1 Location of Bhalyani Settlement at Kullu

IV. Approach for Climatic Design

A building designer should use / manipulate the following major design elements / tools to control the thermal environment in the buildings to suite the climatic conditions of the place [5, 6]:

1. Shape of the building (massing),
2. Fenestration (size, positioning and orientation of windows),
3. Building fabric (insulation & thermal storage)
4. Solar control (shading & surface finishes),
5. Ventilation.

V. Architectural Features of Settlement & Dwellings

A. Spatial Settlement pattern

In the cool climate, the main function of the shelter should be to provide thermal comfort to the occupants by reducing heat loss from the buildings. Therefore, provision should be made in the buildings for solar heat gain, especially in winters, and all the fenestrations should have proper sealing to prevent heat loss. Hence, the buildings should be oriented to the equator, i.e., towards the south and the settlements should have compact layout to reduce heat loss. Here also it was found that the settlement has a compact layout with the dwellings connected by narrow pathways and clustered around courtyards with their openings oriented towards south-east and south-west to take best advantage from solar heat-gain during winter which can be seen in fig. 2.

B. Shape of the Building (Massing)

Traditional dwellings in the settlement are being constructed in a straight forward way based on the functional requirements of the users and the availability of the suitable building materials and construction techniques developed over the centuries to provide comfort to the users from the extreme cold. The dwellings are of two storeys high with linear arrangement of rooms, connected by verandah / balcony, in both the floors. Fig. 3 & 4 shows the typical floor plans, section, and elevation of the dwellings. Normally in the ground floor/level, cattle-shed and storage areas are provided. In the upper level, all the living areas are provided along the cooking area / kitchen; this helps in keeping the surrounding rooms warm during cool night time. Also attic space is provided below the pitched roof covered with shingles / stone tiles. All the wet areas are normally kept separate from the living areas. All the habitable rooms, verandah and balconies are oriented towards the south, east and west to receive the maximum solar heat gain during day time, which are stored in the thermal mass of the dwellings to keep the interiors warmer during night time. Mostly the height of the rooms was kept lower (2.1 - 2.4 m). This low ceiling height helps to keep the interior of the rooms warmer from the heat released by the individuals. Also this contributes to the low surface-to-volume ratio of these dwelling units and thus reducing the heat loss from its surfaces.

Fig. 2 Dwellings are oriented and clustered for solar heat gain

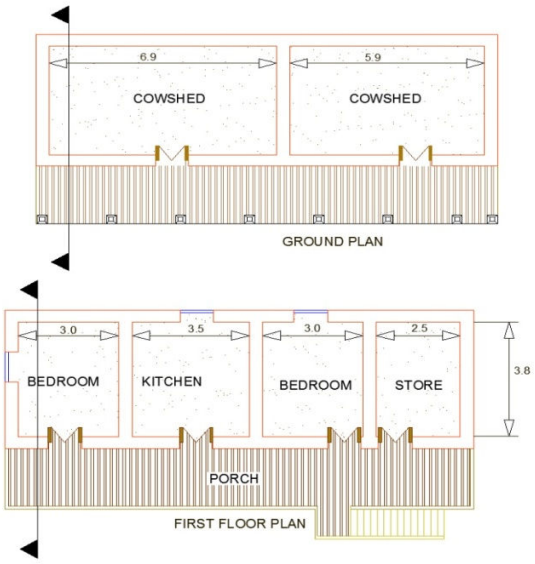

Fig. 3 Typical floor plans of dwellings

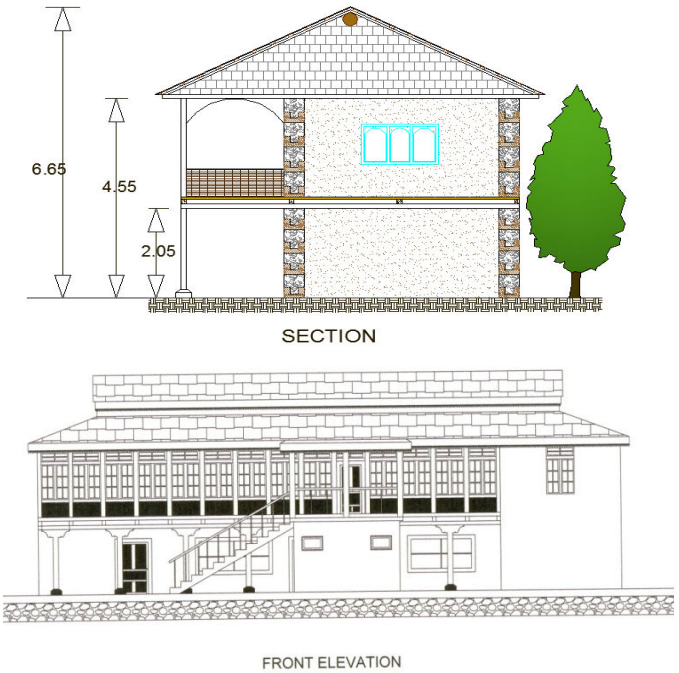

Fig. 4 Typical section & elevation of dwelling

A. Fenestration - Size, Positioning and Orientation of Windows

Small size openings are provided in the rooms of the dwellings with operable timber and glass shutters. Openings were mostly provided on east, west and southern walls. Rooms were single-loaded and connected by timber verandah / balcony. These verandahs are also provided with continuous operable timber and glass shutters, to allow sunlight to come inside the dwellings when open and are kept closed during night-time and winter time, when there are chilled air blowing, to prevent heat loss. The openings at the ground level are protected by the balcony above, and the openings at the first floor are protected by the projection of the pitched roof. No openings are provided in the northern side to avoid the cool winter air. These features also help in solar heat-gain in winter and prevent heat-loss during cooler nights.

B. Building Fabric - Insulation & Thermal storage

In almost all cases, the nature has provided the building materials suitable to the local climatic conditions. In this settlement also, it was found that the dwellings were constructed with locally available timber and stone materials, both having high thermal capacity and low conductivity (k-value in W/m ºC) – for hard timber 0.16 and for sandstone 1.295.

C. Walls

The walls are made of stone masonry and timber having thickness of 45-60 cm. This traditional style of wall construction is known as 'Kath-Khuni' or 'Dhajji-wall' construction method shown in fig. 5. This indigenous style of wood-and-stone construction technique is both practical and aesthetically pleasing. By the systematic process of layering and interlocking the locally available timber and stone materials, the construction becomes inherently strong, stable and flexible to make them suitable to their mountainous terrain that is prone to earthquake. These heavy walls allow a very good thermal insulation by providing high time-lag of more than 8 hours. This makes the interior of the house cooler in summer and warm in winter for maximum part of the year.

Fig. 5 Traditional 'Kath-khuni' wall construction with timber & stone

D. Flooring

In the ground level mud & cow-dung were used for flooring above the plinth made of random rubble masonry. The upper floors are made of timber planks and timber-joists, shown in fig. 6. The use of timber also prevents / reduces heat-gain and heat-loss through floors to a great extent.

Fig. 6 Timber flooring and cantilevered balcony

E. Roofing & Rain Protection

Pitched roofs were provided with rafters and purlins made of locally available slender timbers. Roof covering was done with slate made from locally available stones. Below the roof a ceiling was constructed with timber. The attic was normally used for storing food-grains and also as the abode of the God. The light-weight roof construction and the air between the roofing and attic-floor provided a very good thermal insulation against the passage of heat. The heat stored during the day time of the winter, helped to keep the interior warmer during cool winter nights. Fig. 7 shows the roofing pattern of dwellings in the settlement.

The settlement receives sufficient amount of rainfall through the year. Hence the low pitched roof was a very good solution to drain off the rain-water from the dwellings. Also the roof-edges were sufficiently projected to protect the wall against damage from rain-water.

Fig. 7 Roofing pattern and skyline of the settlement

F. Special Features and Activities

The dwellings are oriented for the maximum solar heat gain, a basic design approach for the buildings in cold climate. Also they have created their indigenous style of sun-space or solarium by using the balcony in the first floor, shown in fig. 8. The natural contour / slope of the site were used for the drainage of rain-water. Sunny courtyards were used to perform various outdoor activities during day-time. Another salient feature observed in the dwellings is the location of the kitchen. They are located on the upper floor, the cooking space – 'chullah', normally made of mad, is placed either at the center or at one side of it. This spatial arrangement helps in keeping the indoor warm even in the cool nights.

Fig. 8 Indigenously built "solarium" or "sun-space" created in dwellings

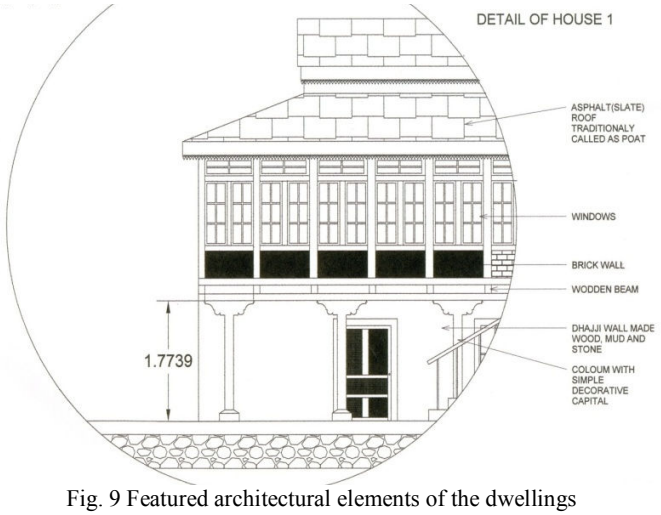

Fig. 9 Featured architectural elements of the dwellings

VI. Conclusion

Above Figure 9 shows the typical architectural elements observed in the dwellings of the settlement. All the construction work is done with the locally available 'Deodar' timber and stone materials as slate. Following figure will summarize the traditional construction method and process that provide thermally comfortable shelter to the occupants by giving due considerations to local climatic conditions.

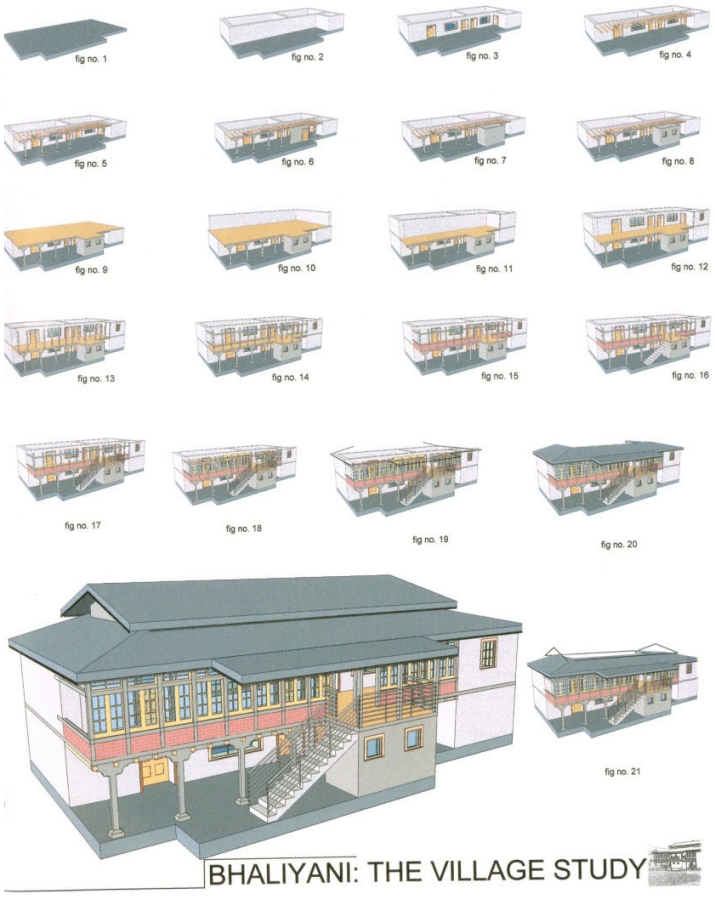

Fig. 10 Construction process of the dwellings in the settlement

From the above discussions it can be seen that this settlements have developed construction techniques and the use of locally available limited resources to adapt themselves with the geo-climatic conditions of the terrain. This construction method have provided comfort to the occupants of the settlement for most part of the year without using any artificial costly source of energy by using materials with less embodied and operational energy. The clothing and activity pattern of the people are also adapted to the geo-climatic conditions of the terrain to provide thermal comfort to the occupants in a very affordable and efficient manner. Therefore, it can be concluded from the findings that due consideration to the geo-climatic conditions of the location will contribute positively to achieve energy-efficiency and thermal-comfort in buildings as well as in the settlement system.

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Ar. Amitava Sarkar (Kolkata, India, 20/01/1977) has obtained his graduate degree Bachelor of Architecture from the University of Madras, India in 2001, and post-graduate degree Master of City Planning from the Indian Institute of Technology, Kharagpur, India in 2003. The author's major fields of study are in architecture and city-planning.He has eight years of industrial and teaching experience after obtaining the post-graduate degree. He has worked as Project Planner at Indian Institute of Technology, Kharagpur, India and as Lecturer in Architecture at Adhiyamaan College of Engineering, Hosur, Tamilnadu, India. Presently he is working as Assistant Professor at Architecture Department, National Institute of Technology, Hamirpur, Himachal Pradesh, India. He has published six research papers in refereed International / National Conferences and eight research papers in refereed International / National journals. His Current research interests are in climate responsive architecture, energy-efficient architecture and building science. Ar. Sarkar is life member of Council of Architecture, India. He is also associate member of Indian Institute of Architects, India and Institute of Town Planners, India. He has also completed consultancy projects worth Rs. 1.5crore.