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Disaster Risk Reduction: Lessons from Traditional Knowledge

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Abstract*: *World over, there is a great shift from disaster management to disaster risk reduction. The Sendai Framework for Disaster Risk Reduction 2015-2030 also focused on to prevention of new risk, reduction of existing risk and strengthening of societal and environmental resilience in process of achieving sustainability. It is a known fact that traditional knowledge has a wealth of knowledge on any subject. This paper is an attempt to review the traditional knowledge related to the built environment of the hills of Uttarakhand, in a process of learning their relevance, to cope up with the threats and vulnerabilities from disasters. The study was conducted and explained through a case study of village Bagori. The qualitative data was collected through an intensive primary survey of the village, discussions with the villagers and available written documents. In the absence of sufficient data availability, the drawings and details of the area were created by the authors, compared and digitized. The analysis of the data was done through GIS (hydro tool) and verified by cross-referencing from the secondary scientific literature. The synthesis of both the spatial and social knowledge reviewed concludes on the possibility of establishing a strong relationship of traditional knowledge in disaster risk reduction. The paper recommends that adaptation of traditional knowledge, dovetailed with contemporary practices will certainly contribute to achieving sustainable development of the disaster-prone region.

Keywords*: *built environment, disaster risk reduction, hill region, sustainability, traditional knowledge, vulnerability.

I. INTRODUCTION

Traditional settlements and dwellings are an integral part of our heritage. These structures are the manifestation of architectural systems developed over time with special consideration to climate, soil and other local materials or natural threats and disasters. It is a model and is a result of the collaboration of many people including the maker and the users of buildings and artifacts and is handed down through generations. This is termed as Traditional as it is developed as a tradition of the society or the location. Since the majority of the population builds their own house, they understand their needs and requirements perfectly; any problems that affect the design are dealt with personally and necessary modifications are done, if possible, in the same building or in the later developments. There may or may not be prescribed ways of doing and not doing things. Through their experiences and trial and error procedures, the model is finally adjusted until it satisfies most of the cultural, physical, and socio-economic needs. The traditional architecture in hill regions of Uttarakhand has its own peculiarities that have been developed through the experience of generations and provide the methods of site planning, building design, and modification, the adaptation of existing technologies and structures, propositions as to the alteration of layout forms, plan types and technologies that suit the local conditions. Using local material, the residents have developed techniques of making safe the timber constructions that have withstood the frequent earthquakes and floods while managing the particular cultural requirements.

In fact, the communities living in India, in disaster-prone areas, have developed survival strategies and built their traditional settlements and dwellings (Oliver, 2006) to meet their specific needs through their traditional knowledge skills for coping with the stresses from natural hazards. It is evident from the surviving cases of folk traditional dwellings, for example, *Bhungas* in Gujarat, bamboo houses in Bihar, and wooden houses in Kashmir (Langenrbach, 2009), that are constructed using local materials with proper construction techniques and detail (See Figure 1).

Food in Bihar in 2008: buildings built using bamboo could resist the disaster. (Source: Langenrbach, 2009)

Earthquake in Kashmir 2005: buildings built with local material and construction techniques survived (Source: Langenrbach, 2009)

Earthquake in 2001, Gujrat: Bhungas were the intact structures (Source: Madhusudan Choudhary, 2002)

1000 year old Earthquake safe structure at Koti-Banal (Source: author)

Figure 1: Survivors, built structures of various disasters

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Such traditional knowledge of creating built environments is gained over centuries, transmitted physically and orally from generation to generation and most often is linked to their culture, experiences, and skills, which has developed over time. The challenges put forth by climatic and physiographic conditions make human survival by adapting the environmental situations and coping with it (ISDR, 2008). Traditional architecture developed in adverse conditions can be analyzed in physical and spatial form for taking out future references.

It has been also well noticed that disaster risk is increasing exponentially worldwide, due to increase in vulnerability as the poverty and environment is increasing every day; the climate changes and loss of flora has increased the number of natural hazards; and the exposure to poorly planned development (See **Error! Reference source not found.**) The United Nations is also giving greater attention towards building "Disaster Resilient Communities" by promoting increased awareness of the importance of disaster reduction as an integral component of sustainable development.

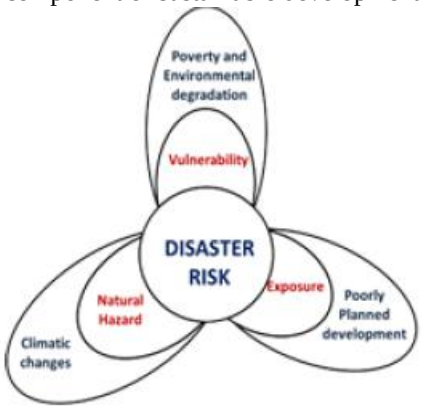


Figure 2: Increases in Disaster Risk. Source: adapted from IPCC 2012

Internationally, it is accepted to integrate a multi-hazard, inclusive approach to address the vulnerability, risk assessment, and disaster risk reduction, an essential element of a safer world in the twenty-first century. The Sendai Framework for Disaster Risk Reduction 2015-2030 focused on to prevent new risks, reduce existing risk and strengthen societal and environmental resilience through local knowledge. It is also encouraged to the dissemination and use of traditional and indigenous knowledge to mitigate the impact of disasters and promote community-based disaster management planning.

Uttarakhand, an Indian Himalayan state known for its rich spiritual and religious tourism, ecological richness and diversity, and cultural ethos rooted in tradition, but is also known for its growing frequency and intensity of natural multiple disasters (National Institute of Disaster Management, 2015). Despite the topographical and climatically challenges of the region, various traditional dwelling remains intact and survived many earthquakes (Rautela & Joshi, 2008). This paper argues that traditional knowledge applied in framing the physical setting of the hill settlements and its traditional dwellings has significant relevance to cope up with the threats and vulnerabilities from disaster risks. This knowledge can be used even in contemporary buildings also.

II. THE STUDY AREA

Out of the total geographical area of the Uttarakhand state (53,483 sq.km), 86% (46,035 sq.km) is hilly that faces multiple disasters such as earthquake, landslides, cloudburst and flash floods, etc. Many rivers like Ganga, Yamuna, Alaknanda, Kali, and Bhagirathi along with their tributaries originate in the State. Historically it is evident that the earlier settlements are on the river banks. Similarly, the river valleys and the transverse spurs offer convenient sites for the settlement in hilly areas as they provide a convenient source of water. People have been settling down in these hilly areas for ages and have been looking after the pilgrims visiting important mythological places located in these hills. The residents of these hills have, in due course of time, developed some important construction styles suited to these hills. Some of the construction techniques developed include *Kath-Kuni*, *Kothi*, *Dhajji-Dewari*, *Taaq* system, stone houses, mud houses, and wooden houses (Kumar & Pushplata, 2013), etc. It has been noted that these techniques have matured and passed hands from generation to generation according to the local climatic, geographical and environmental requirements and well adopted for making dwellings. These settlements located in the multi-hazard region have survived these vagaries. This fact led to the inquisitiveness to study the traditional architectural language developed in the hills of Uttarakhand and to establish if these techniques would be relevant today in reducing disaster risk in a similar multi hazardous region. To study the traditional knowledge, being a qualitative base, it is required to go for a case study approach.

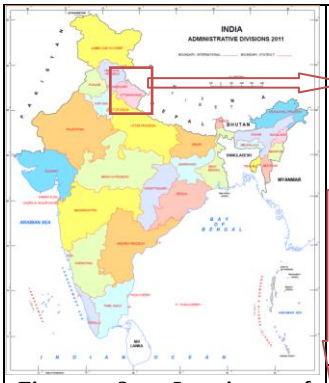


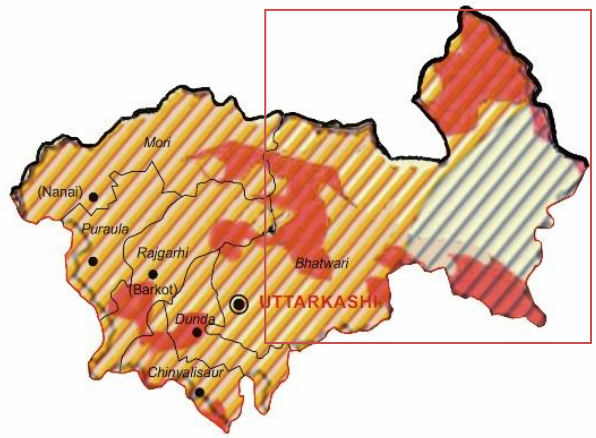
Figure 2: Location of Uttarakhand in India, *Source:* http://censusindia.gov.in/2011census/maps/administrative_maps/adammaps2011.html

Figure 3: Garhwal and Kumaon division n and longitudinal division

Figure 5: Uttarkashi district in the Garhwal division

Longitudinal Uttarakhand is divided into five zones as Tarai, Shivalik-Doons, Lesser Himalaya, Greater Himalaya and Trans-Himalaya based on the thrust or faults (**Figure 3**). Hill region of Uttarakhand fall under Lesser,

Greater, and Trans-Himalaya. Trans-Himalayas have high snow mountains and extremely low temperatures and so unsuited for habitation. Uttarakhand has two major divisions as Garhwal and Kumaon (*Figure 3*).



	Earthquake Zone V
	Earthquake Zone IV
	Landslide Zone

Figure 4: Overlapping of Earthquake and Landslide zones (Source: http://dmmc.uk.gov.in/pages/display/95-earthquake-zone http://dmmc.uk.gov.in/pages/display/96-landslide-zone) and then selecting Bhatwari block for study

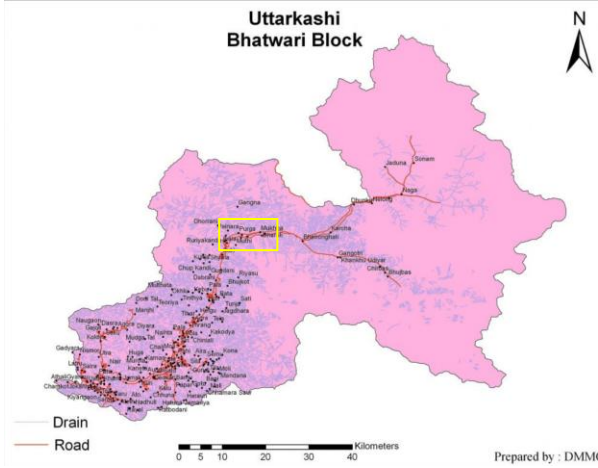


Figure 5: Location of villages and drainage pattern in Bhatwari block

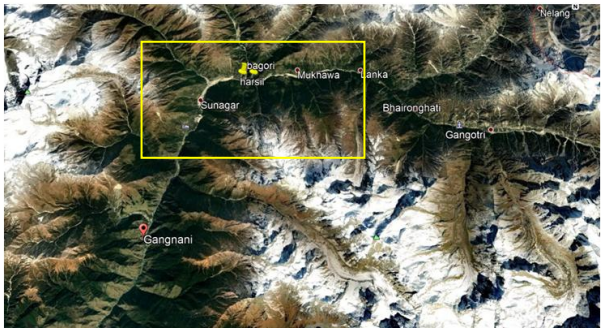


Figure 6: Location of Bagori villages along Bhagirathi River, Source: Google Earth

For the study hill region of Garhwal and Uttarkashi district is taken, as it is having more population and traditional houses located in a village. On overlapping the Earthquake and Landslide Zone, It is found that Bhatwari Block encounters both types of severe hazards in the region (*Figure 4*). To understand the phenomenon and the relationship between traditional knowledge and disaster risk reduction, a case study of village Bagori, Bhatwari block, Uttarkashi District is taken (Figure 6 and Figure 5).

A. Method of data collection

On-field visit to Bagori, conducted by authors in July 2017, it was noted to be having 567 resident population in 145 households, located on the banks of river Bhagirathi (*later Ganga*), near Gangotri (*starting point of river Bhagirathi)* in Greater Himalaya. A qualitative and inductive approach was adopted, and data was collected through the following methods:

- Interviews and discussions with the residents.
- Photographic and video recording
- Documentation of the dwellings
- Direct and indirect observation
- Secondary sources through available literature

B. Method of analysis of the data collected

The study is restricted to two aspects. The first assessment is restricted to the built environment that includes the geography and landscape, settlement pattern with its street layouts, the arrangement of plots, building layout, and materials used for construction and construction details. This is analyzed on the basis of the illustration and documentation done on-site.

The second aspect reveals the social setup for which the data was collected through interactions with the inhabitants during the field visits that explains both the direct and latent understanding of the traditional knowledge and its relationship with spatial and built form. It also has provided an insight into the limitations of traditional knowledge and its applications in contemporary practice. The verbal conversation was transcript and grouped to analyses.

Through the thorough synthesis of both the spatial and social considerations, this study tries to derive inferences on the direct and indirect relations of traditional knowledge in disaster risk reduction.

III. FINDINGS FROM THE STUDY AREA

On the basis of the data collected, authors have tried to bring out the understanding of the traditional knowledge system and its link with the disaster risk reduction in the form of the finding from the case study done.

A. Spatial and Built Form Assessment

Understanding the physical and natural setting of the built environment developed over a long period by the people itself is mapped by an intensive primary survey. Measured drawings were prepared and compared from the google earth images. The developed illustrations were used to document the existing built form patterns. At a macro-level understanding of the nature of disaster impacts, GIS (hydro) tools were adopted to identify the stream nature and order.

Relevant secondary sources were also taken into consideration whilst establishing a link between traditional knowledge and disaster risk reduction.

Figure 7: Location of Bagori between two folds, along the river

Figure 8: Entrance of the Village

Figure 9: Buddhist temple is located near the entrance of the village

1) Geographical Landscape

Uttarakhand lies on the south slope of the Himalaya range, and the climate and vegetation vary greatly with elevation, from glaciers at the highest elevations to tropical forests at the lower elevations. Bagori is located at latitude 31°01′59″N, longitude: 78°43′59″E. It is away from the geographical fault zone, known as the Main Boundary Thrust (MBT) and Main Central Thrust (MCT) (*Figure 3*). Geographically, its strategic location reduces any type of regional hazard and considered a safe regional location (National Institute of Disaster Management, 2015). It is situated in the river valley (Figure 6, **Figure 13**) and surrounded by mountainous peaks. Apart from *Matr*i and *Kailash* mountains, on the right side, there is the *Shrikanth* peak, behind which lies *Kedarnath*, and in the rear there is *Banderpunch*. The main tribe that settles here are *Bhutias*, the shepherd and follow Buddhism (**Figure 9**). It is observed that Bagori flourished between the two folds formed in the terrain (**Figure 6**). Because of this natural setting, the seasonal water drainage will pass through the sides without affecting the settlement. The layout and its geographic landscape has been analyzed using ARC GIS – Hydro tools, and mapped the stream patterns first and then further analyzed the degree of stream orders, which significantly has demonstrated that the settlements were located in the safer zone. Being on river valleys and transverse spurs on one side offer the convenient site for settlement. As it is very close to the starting point of the river, the stream is narrow, but with high speed and the flow of water is governed by the natural contour itself. River valley provides facilities of carving out terraces for agriculture, water sources, and pastureland. Cattle as sheep are the main cause of settling down in this high altitude. Sheep provide them wool, which is the main source of income. The cold and congenial environment has attracted a nomadic pastoral group of people to settle in the green pastureland of Uttarakhand. Deodar forest as vegetation indicates habitat sustainability in this area. Trees and wood for fuel for domestic use and construction materials are abundant. Agriculture is the secondary occupation of local people. Bagori is known for its apple orchard, all around.

Figure 10: Passage between the buildings

Figure 11: Apple orchard towards the river and hill

2) Settlement layout and its pattern

The habitable residential area is on the foothill where the contour level difference is less; whereas the agricultural farmlands are toward the river and hillside, (See Figure 12 and Figure 11). This settlement pattern and location of permanent built forms and people away from any possibilities of flood during heavy rainfall or cloud burst.

The main street, 2.5 meter-wide, runs from east to west, which is parallel with contour or river. The linear settlement pattern is seen (See Figure 12), which has a Buddhist monastery at the entrance to the village. It is interesting to observe that most of the residential units are placed perpendicular to the street. The shorter side of the house is perpendicular to the contour. That means the impact area of a dwelling unit in case of flood from riverside or landslide from the hillside is reduced. Moreover, each unit is isolated and separated by an accessible walkway of at least 1 meter in between (See Figure 10), which is an ideal model in case of an earthquake. Individual building behaves as a single entity as a structure and has no interconnection with the other buildings. There are no built structures constructed towards the riverside so that the settlement remains safe when there is a rise in the water level of the river.

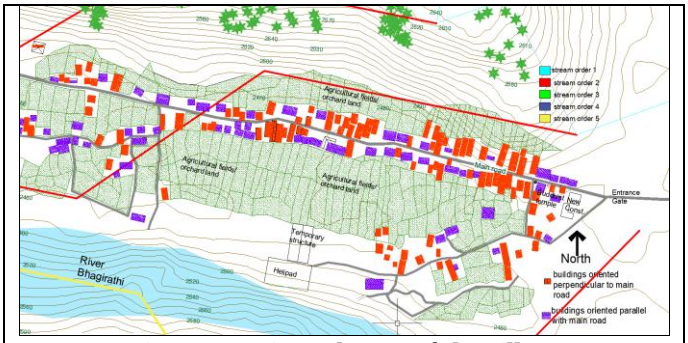


Figure 12: Linear layout of the village

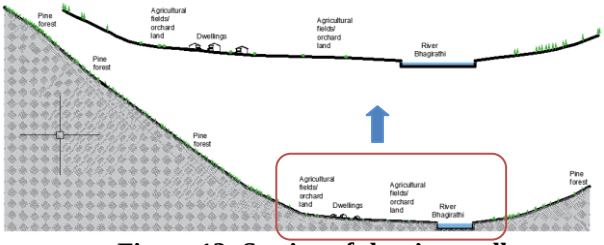


Figure 13: Section of the river valley

3) BUILT FORMS

Buildings are simple, regular and often symmetrical (See Figure 18) in both plan and elevation, produce less magnitude of twist during any hazard- landslide, flood, earthquake, cyclone, etc., and are considered to be very stable (Arya, 2001) (Biswas, 2006). Dwellings in Bagori are composed in rectangular forms and are two-storied in height. The ground floor is `on stilt and used for cattle and fodder while the upper floor acts as living spaces with the number of rooms on one side and long verandah (See Figure 18Figure 18: Exploded view of a typical dwelling). Semi covered verandah is usually used for social interaction (See Figure 16) and as well as livelihood space and sometimes a part of it functions as a temple, toilet or kitchen. Stilted structure helps the people during the time of flood, landslides, and snowfall. There are no cantilevers or large projections used in the buildings and this qualifies to the statement of Arya (2001) who considered large projections as vulnerable in an earthquake and undergo high deflections and reversible stress that lead to damage of the structure.

Figure 14: Stilted house built using stone and timber, and then plastered

Figure 15: Stilted house built using stone for the lower floor, while timber for wall and floor

Figure 16: Balconies as an activity area and facing towards the sun

Figure 17: Joinery details

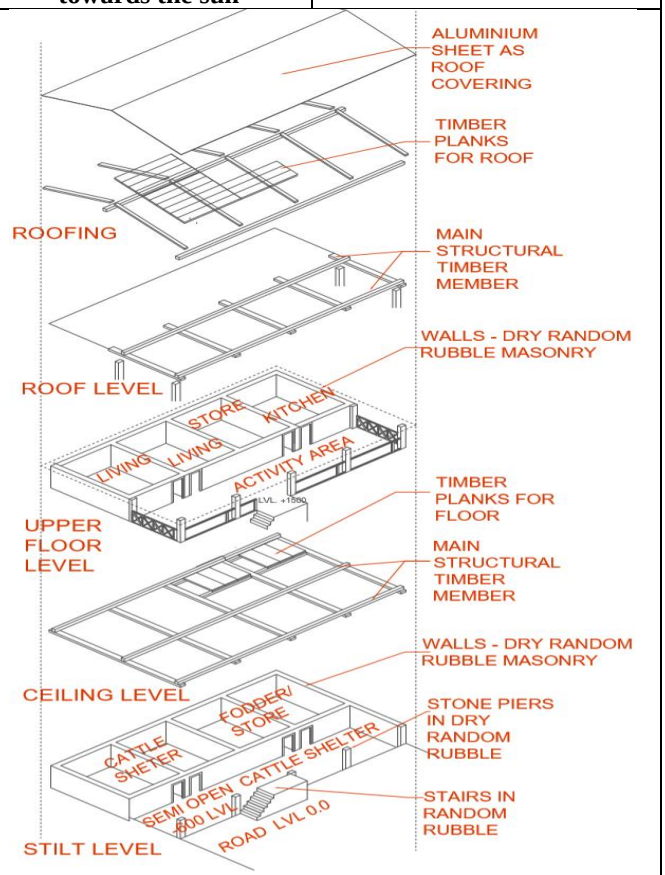


Figure 18: Exploded view of a typical dwelling

4) Building material and structure

The habitable composite structure is built of locally available timber and stone.

The columns for stilts are constructed using stone chips, whereas the walls are constructed by making the frame of timber and infill of stone in between the voids (See **Figure 14**) or timber planks itself (See **Figure 15**).

The compressive property of stone is well utilized in walls that consist of wooden cribbage configuration with orthogonally arranged wooden logs interconnected at the junctions (See **Figure 17**) by wooden pins/ tennons joinery (*Gujja Khoonta*). The upper floor used as a living area has a complete floor of timber. The stable frame structure is well constructed as it can bear the various external forces occurring in this region.

Timber is a strong, elastoplastic and fibrous material, which is available from the pine forest from the nearby and is used for the basic framework of the structure. It has the ability to absorb the various types of vibration and is also climatic responsible material for this cold region. Both housing and nailing techniques are resorted to joining the wooden components which allow for minimal angular displacement. This kind of joint incorporates advantages of both pin joint and rigid joint and acts as a semi-rigid joint, which is an additional advantage for shock resistance. Stone is generally used as infill material in these structures, play a vital role to resist various live forces. The compressive and absorptive property of stone is well utilized in this region.

B. The narrative from the Field Surveys

The intensive survey on the site was conducted and information collected in the form of field notes, narratives including oral history and open and semi-structured interviews. The following section discusses the analysis based on the primary data. The verbal communications collected from the diverse responders were transcribed and highlighted the major issues and coding was done.

1) Natural Setting

Indigenous ways of observations used by people for selection of site has helped instability over the ages. The system adopted with respect to topography can be adopted for future works. The animals and birds are more sensitive than humans and give various indicators or produce sound at the time or prior to the occurrence of any disasters. We need to be sensitive to animal behavior.

2) Vegetation

Green vegetation indicates the presence of sunlight and water. It also indicates landslide and other disasters free area. Non-resident species such as Pine or *Chir* gets affected by a termite and stop the growth of small shrub and grass below them adds to the venerability. Such species need be avoided

3) Development

Unmindful development such as cutting of hills for new roads and widening has increased the physical vulnerability of hills and has decreased the stability. Proper care needs to be taken for stabilizing the remaining hill. Deforestation increased for development required cutting of trees that lead to loosing of the soil. The residents have felt it. The awareness and protection need to be made an inherent part of the development plan. An increase in tourism in the hill region has invited many non-resident developers who are not aware of the traditional technics and try to adopt plain lad technics to the hills resulting in adverse effects on the stability. It should be mandatory for the developers to follow local site planning and construction technics.

4) Settlement Pattern

During the harsh winters, the community along with cattle moves to a lower altitude for survival. This shows the sensitivity of the residents to the changing environment. The residents, through experience, have developed a linear pattern and have also defined the limitation with the natural features, like major streams on both sides and on the other hand river and steep slopes for future expansion. The greater study is required to provide such limiting factors in the hilly region.

5) Building typology

Rectangular, Isolated and detached building typology has developed through experience. The residents have developed un-written Byelaws for site planning and distances between the two blocks for providing clear passage to rainwater without disturbing the natural drainage system. Such indigenous understanding demonstrates the architectural sensitivity in seismic areas. Stilt shelter for cattle and the upper floor for living space clearly indicate climatically responsive design. The upper floors are considered safe in case of floods and landslides.

6) Local material

Timber and stone used are local materials and are fully recyclable. Local wood withstands the climatic changes and is sustainable. Both wood and stone are also good in withstanding disasters as such more sustainable than others.

7) Structure system

The wooden frame cribbage and with dry infill of small pieces of stone known as *Katli Chinai* uses no cement with mud plaster over the stone infill. The life of both mud and stone is unlimited and much more than cement. The cross-connection of wooden posts gives greater strength and stability and most suited during disasters.

IV. DISCUSSION

It is important to understand the relevance of traditional knowledge in the present time. Some suggestions based on the study are as follows:

A. Timber as Raw material

The government of India has restricted the use of wood as deforestation and export of wood are leading to its shortage and various other ecological issues. This is due to the unmindful destruction of forests and no plantation of fresh saplings. The residents of the area had associated tree plantation with and religious activity- birth, marriage or even death. The process was adopted by all and did not allow a shortage of different species. We need to encourage it and try to re-establish the practice.

B. Stone as Raw material

Due to various construction activities in and around the area stone is becoming scarce but smaller pieces are still available in abundance and can certainly be used for traditional infill work with columns and cross beams of RCC.

C. Community Participation

Community involvement in the construction of houses was once the way of life of the villages but has become extinct due to various reasons. The family sizes have reduced and the availability of able persons is not there. Construction has become an individual activity and it is difficult to revive the old practice. Dependancy on market availability of material and labour can not be ruled out.

D. Skilled labour

The availability of skilled labour is reducing day by day. The skilled labour is migrating to a larger settlement for a better prospect. System to revive local skills shall have to be developed in conjunction with the provision of contemporary skills.

E. Lifestyle Changes

Living and working habits have changed. The impact of cities is really seen on the hill also. This is a welcome sign and shall have to be suitably adopted in the building designs.

F. Access to contemporary material and Technology

Due to better communication and road network, modern construction material such as cement, steel, tiles, etc. are available in the hills as well. This is a welcome development but attention shall have to be given in its use and proper dovetailing with traditional skills shall have to be done to be relevant for the sustainability of the region.

V. CONCLUSION

Traditional knowledge, passing hands from one generation to the next generation is the outcome of a holistic response to several tangible and intangible factors that form the contextual environment. The zeal to protect the community by utilizing accumulated traditional knowledge and experimenting with local available building material, paved the way for the evolution of the dwelling raised up and constructed on stilts near to the river. The built form which is the result of various planning and architectural practices has sustained multi-hazard over a longer period, clearly showing its versatility. This is a result of the practice of a thorough understanding of the surroundings and giving due respect to it without disturbing the streams and other major features.

Although the residents are aware of the importance of the traditional building typology and setting which contributed in surviving the impacts of disasters for generations and help in preventing and sustaining the risk form multiple disasters, the traditional art is under threat of extinction due to vanishing construction expertise and longer duration in the process of construction. Depletion in the green cover and loss of the species of plants required and ban on cutting of the trees has added to the change in process from traditional to the modern RCC work.

The study reveals great insights in wisdom of selecting safe places for dwelling, architectural planning and details to survive multi hazards, wise use of landscape for agriculture and other economic activities and in preserving ecosystems for survival and sustainability. The adaptation of this traditional knowledge dovetailed with contemporary practices will certainly contribute in the sustainable development of such disaster-prone regions. It shall be pertinent to propagate the traditional site planning practices to attract the attention of the developers of similar regions, to promote these learnings. It shall also be important to frame the planning and operation guidelines, properly dovetailing the traditional and contemporary practices. It is recommended that to show respect and confidence, the government projects should invariably and consciously include the local materials and construction techniques and encourage people to participate in designing and execution phases. This will not only create employment opportunities but also can build faith amongst the people and community in the traditional construction using modern knowledge. The authors see great wisdom in protection of these vanishing traditional settings technics, building design and construction techniques and are sure that it will not only instill a sense of pride for the traditional wisdom of the ancestors, will also enable the future generations to have a glimpse of the architectural tradition of the region that have lot of validity for the present times.

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