Adaption Options for Building Infrastructure in Northern India in View of Changing Climate

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Abstract

Regardless the causes of climate change; the changing parameters such as increased temperature, amount and intensity of precipitation may put current buildings at risk in terms of their service life. The design guidelines, material selection and construction techniques for a region should be re-looked to improve the performance of the buildings in relation risk due to the changing climate impacts to that region. The Himalayan region of India is considered to be one of the most vulnerable ecosystems across the globe, with a higher global warming average than the world and about 70 percent of total geographical area of states such as Himachal Pradesh in the western Himalayas being vulnerable to floods. Based on the projected climate change data for this region this paper presents the impacts of climate change on traditional construction types in this region. The paper primarily focuses on literature survey to present possible adaptive strategies in terms of building materials and construction techniques. In addition, it briefly addresses other possibilities of improvements in standards and codes relevant for construction practices in this region.

Keywords: design guidelines, material selection, construction techniques, adaptive strategies, standards and codes

Résumé

Si l'article est en français, le résumé français sera le premier.

Mots clés : conférence, article, modèle, dix mots maximum

1. Introduction

The Indian Himalayan Region is one of the most vulnerable ecosystems in the world consisting of a 70 million strong socio economically weak population. The changing climate scenario in this region has direct impacts on the vernacular construction of this region and adaptation strategies have been designed keeping in view the cultural heritage and the livelihoods of people in this area.

The paper discusses the changing climate scenario based on the report of IMD (Indian Meteorological Department) and the INCCA (Indian Network for Climate Change Assessment) and the impacts that these changes have on the frequency and amount of extreme events that take place in the region. Based on these the indirect impacts on building construction in the region are discussed by classifying them on the basis of the common materials used in the region for construction.

The adaptive strategies required aim at two different aspects of adaptation. The first kind of strategies focus at increasing the durability of materials so as to combat against deterioration due to action of different climatic agents. The second form of strategies aim at incorporating unconventional construction techniques and design guidelines in the construction and renovation of buildings in order to make them less prone to failure in extreme calamities such as landslides, floods, cloud bursts etc. all which are direct impacts of the changing climate.

Finally the paper briefly discusses the role of building policy makers and building codes, and how amendments in these aspects will play a crucial role in the implementation of the discussed adaptive strategies

2. Climate profile

The Himalayan region in general has an alpine climate with occurrence of heavy snowfall during winter months of December to February at altitudes above 1500m. Rains usually occur in the months of January and February over this region and heavy rainfall is observed across the foothills of the Himalayas during months of July to September. The northern side of the western Himalayas is an arid region with scanty rainfall and severely cold winters. Most of the precipitation is in the form of snow during late winter and spring months. The southern Himalayan region is protected from cold winds coming from interior of Asia during the winter. The leeward side of the mountains receives less rain while the exposed slopes experience heavy rainfall. The places situated between 1070 and 2290 m altitudes receive the heaviest rainfall and the rainfall decreases rapidly above 2290m. The temperature falls by 0.6 degree Celsius for every 100 m rise in altitude. The states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, and Arunachal Pradesh fall under this climate zone [1]. During the period 1901-2007 All India mean annual minimum temperature has significantly increased by 0.27°C and spatial change in minimum temperatures is observed to be increasing for most parts of the Himalayan region. Most of the glaciers of western Himalayas are receding. Kripalani et al (2003) have reported that the spring snow cover of western Himalaya has been declining and the snow was melting faster from winter to spring after 1993, which is consistent with the current trends observed [2]. Based on data obtained by INCCA (Indian Network for Climate Change Assessment) through the PRECIS climatic model, an overall rise in precipitation and temperature of this region is predicted for the 2030s. Table 1 shows the climatic parameters affecting the region and their projected changes for 2030s with respect to 1970s [2].

Climate Parameter	Projected Change	Remarks
Annual Temperature increase	0.9±0.6°C to 2.6±0.7°C	
Net Temperature increase	1.7-2.2°C	Decrease by 2.6°C is expected for winter months
Annual Rainfall	1268±225.2mm to 1604±175.2mm	Average increase is by 5-13%,
Rainfall Intensity	Increase by 1-2mm/day	No.of rainy days increase by 5-10 days on average in complete region

2.1 Direct Impacts of Climate Change

In line with the projected changes in climate, the impacts can be seen across the region. According to the International Centre for Integrated Mountain Development (ICIMOD), global warming in the Himalayan region has been much greater than the average global rate. The average temperature of Shimla has increased by about 1°C in the past 100 years [3]. The increased precipitation and mean monthly air temperature will result in an increased rate of glacier retreats and frequency of extreme events such as landslides, cloudbursts in catchment areas which in turn will result in flash floods, causing severe damage to buildings. According to an assessment made by Central Water Commission in 2000, 70 percent of the geographical area in Himachal Pradesh is vulnerable to flooding. Other effects of disasters such as landslides will include intense soil erosion, diversion of water systems, and deterioration in quality of surface water, which is a threat to both buildings and the region's natural resources such as forests. Freeze thaw cycles resulting from melting and refreezing of snow will alter soil properties such as moisture content which in turn may have an adverse effect on soil strength and hence put building foundations to risk.

2.2 Impacts on Building Construction

The major population of the states within the Himalayan region resides in rural or small town areas. Construction is majorly vernacular and informal in nature, making use of natural resources available. Timber, stone masonry and mud bricks (adobe) are the common building materials used. Some of the traditional construction styles include *Dhajji Dewari*, also referred to as Brick nogged Timber Frame Construction by the Indian Standard code, and is found in the western Himalayan region. In the arid regions of Himachal Pradesh, such as the Sipiti valley, typically Mud Wall Construction is used, while in the wetter regions of the state, which experiences heavy rainfall and snow (October to march), houses incorporate the combined use of timber and stone for vertical and horizontal frame members. However due to years of exploitation of natural and locally available resources dry stone masonry has become a recent construction practice in regions where scarcity of wood is a problem. The construction is similar to the traditional styles except for omitting the use of wood. [4][5][6]

The projected climate change scenario will have multiple impacts on the building materials, increasing the vulnerability of these buildings to gradual deterioration and failure in extreme events. The impact maybe all the more high as the majority of the houses are made by local masons with sometimes the direct involvement of the owner, in the construction process. There is no role of architects or engineers in the design or construction of the buildings and the owners also usually decide the quality of the material used.

2.2.1 Impacts on Timber Construction

Timber is extensively incorporated in frame as vertical and horizontal elements and as a roofing material. Increased rainfall and mean air temperature will result in degradation of timber due to moisture penetration and the lower possible reason of formation of wood deteriorating fungi. Increased snow loads may cause additional structural problems such as sagging of wooden members that would result in compromised strength and structural stability of the building as a whole. For buildings using timber pile foundations the effect of increase in soil and land moisture content may only cause damage when accompanied by freeze thaw cycles, since repeated drying and wetting will lead to shrinkage and expansion of wood leading to uneven settlement. Depending on the building design an increased risk of failure shall exist due to increase in relative humidity. [4][7][8]

2.2.2 Impacts on Stone Masonry Construction

In certain areas of Himachal Pradesh with wood scarcity, recent construction techniques employ dry stone masonry, which is similar to the traditional construction but omits the use of wooden elements. While stone is a strong material with little scope of abrasion or damage of any sort, however along with the sustained action of climatic agents acting on it, certain deterioration does take place such as premature aging caused due to thermal stress created due to freeze thaw cycles, increasing the vulnerability of the structure towards extreme events. Higher temperature and higher precipitation also imply increased risk of salt damage. [6][7]

2.2.3 Impacts on Adobe Construction

Adobe wall or sun dried mud brick wall construction can be seen in the cold arid regions such as Sipiti and Lahaul valleys of western Himalayas. With increased rainfall and rising temperature trends and the existing effects of snowfall and wind loads, building with this typology of construction both residential and historic, face high risks of climate caused deterioration including moisture penetration, efflorescence caused due to salt formation, and premature deterioration due to freeze thaw cycles. Action of wind along with the impact of rain is a major cause for erosion of external renders and loss of surface material. Load bearing walls of structures are also affected by water intrusion. The combined action of other mentioned climate agents also impact the structural integrity of such buildings. [5][8]

3. Adaptation Strategies

To deal with the impacts of climate change building adaption options need to look into two different aspects. The first type of strategies focuses on improving materials in order to make them more durable against climatic agents acting on them and reducing their rate of degradation. The second form of strategies shall focus on design guidelines and construction techniques so as to improve overall structural integrity and reduce the risks of building failure during extreme climatic events.

3.1 Adaptation options for Timber construction

Use of CGI roofs in place of timber can prove as a good barrier to rains

Natural Bark Singles (NBS) provide a good alternative for a weather resistant external finish with no environmental impact of chemicals/ preservatives in the product

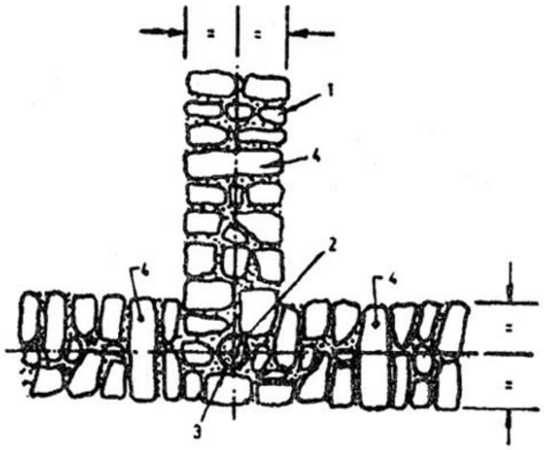
Though biodegradation is not a major issue currently, however with the projected climate changes indicating increased precipitation and temperature, which is likely to speed up bio colonization, materials with low water retention such as coarsely porous materials will be less prone to the effects and can be used as an alternative. [7]

3.2 Adaptation options for Stone Masonry construction

Dressed stone masonry in stretcher bond (for buildings that will be constructed)

For existing buildings horizontal reinforcement for load bearing masonry is important to increase resistance to failure in events such as floods or earthquakes. RCC bands or wooden bands are available options. [6]

Vertical steel reinforcement can also be used in stone masonry to improve structural integrity (Figure 1) [9].



1. Stone wall, 2. Vertical steel bar, 3. Casing pipe, 4, Through stone or bonding element.

Figure 1

Air entraining agents or the use of gap-graded sands in pointing mortars can increase the frost resistance of masonry. [7]

Salt resisting materials such as salt transporting or salt accumulating plasters can be used. Mortars mixed in crystalline inhibitors are also a promising option. [7]

3.3 Adaptation options for Adobe construction

The adaptive strategies required are more or less similar to that of those required for other forms of masonry.

Some additional strategies can include the use of moisture resistant cement concrete blocks or stabilized compressed mud blocks for new construction and making renovations to existing construction. [8]

The use of Geomesh reinforcement during adobe wall construction can result in adding to the structural strength of these houses. This strategy has been widely adopted in rural adobe houses in Peru. [10]

3.3 Adaptation options – General Design and Construction Techniques

High performance exterior envelopes making use of permeable materials as exterior sheathing should be used to allow moisture to escape. [11]

Pressure- equalized rain screens can be used as a building face seal strategy. [11]

Air and vapour retarders installed towards the interior of the wall will protect interiors from getting wet

Cavity wall construction can be used for buildings to increase efficiency of building envelope. However this is not a prominent technique in rural construction but can be used for public buildings. [12]

In urban buildings that use RCC slabs for roofing, a replacement on the bottom side can filler slabs using earthen pots as concrete only acts as support for reinforcement and does not as such contribute to the load bearing ability. [12]

Resource Efficient Bricks (REBs) are another option available for using as roofing materials. They are perforated or hollow, lightweight and act as good insulators. [12]

Dome shaped roofs can act well in dealing with snow loads, as they wouldn't allow accumulation of snowfall.

4. Scope of Improvements

Buildings in this region are developed by the people without any technical or professional training hence the major factor in the successful implementation of the strategies discussed in this paper will be based on the role of governing authorities, building policies and codes. Currently the Indian building code for hilly regions, IS14804: 2000 [13] has a major scope for revision. Some points of improvement are listed below:

While the code discusses the materials used in houses of this region, information on properties of majority of the materials is lacking.

The Code is based on past experience and discusses the practices already being followed in the area. Keeping in view the changing climate, codes should now be revised to be more responsive in adapting to the changes [14]. An example of this could be a provision for a separate code on hygrothermal analysis. Hygrothermal analysis considers interior climate, temperature and humidity as environmental loads with principle limiting conditions such as corrosion, decay, rot and mold. A damage process is used to determine whether a limiting condition such as mold growth is achieved [11].

A link between policy makers, building professionals and building artisans needs to be established to circulate knowledge regarding climate change and the need of changing or improving construction practices to adapt to it. This would allow imparting an understanding of building materials and the impacts on them and also helping people (local masons and building owners) to learn how to incorporate features in their buildings to make them more climate resilient. A major step in this direction would be establishment of a local building code for the area keeping in mind the vernacular construction practices, their advantages and drawbacks. Regulations of this sort would eventually lead to better quality of materials used and better workmanship in construction of these buildings. [3][15]

5. Conclusion

The climate change scenario discussed by the INCCA for the Indian Himalayan region has impacts in various ways across the region. The increased temperature and precipitation trends have directly affected the frequency and intensity of extreme events which inturn have their effects on buildings. Hence adaptive strategies focusing on increasing durability of building materials, design and construction techniques have been discussed in this paper. These strategies are suggested keeping in view the importance of vernacular construction and aim at strengthening it to maintain the region's cultural heritage with an understanding of the lifestyle of the people living in it. The successful implementation of these crucially depends on building policies, codes and the relationship between policymakers, construction professionals and the local public. A large scope exists for amendments in existing codes and the requirement of local codes specific to the area.

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