

Climate responsive building design strategies of vernacular architecture in Nepal



Susanne Bodach^{a,*}, Werner Lang^a, Johannes Hamhaber^c

^a Institute of Energy Efficient and Sustainable Design and Building, Technische Universität München (TUM), Germany

^c Institute for Technology and Resources Management in the Tropics and Subtropics, Cologne University of Applied Sciences, Betzdorfer Straße 2, 50679 Cologne, Germany

ARTICLE INFO

Article history:

Received 11 January 2014

Received in revised form 15 April 2014

Accepted 14 June 2014

Available online 23 June 2014

Keywords:

Vernacular architecture

Nepal

Bioclimatic design

Climate responsive building design

Developing country

Traditional building techniques

ABSTRACT

Vernacular architecture is the result of hundreds of years of optimization to provide a comfortable shelter in a local climate using available materials and known construction technologies. Due to the absence of mechanical means, traditional buildings use solar passive measures to achieve thermal comfort conditions. In most developing countries it can be observed that with the modernization of the building sector this traditional knowledge of smart and climate responsive design is being lost. Instead the modern building design is dominated by universal architecture that neglects local climate conditions and traditional construction techniques and materials. This paper reviews examples of vernacular architecture and its building elements in Nepal and analyses in a qualitative manner which bioclimatic design strategies were applied.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

Worldwide around 40% of energy is consumed in buildings [1]. Due to population growth, increased urbanization and improvements of living standards most of energy consuming buildings will be located in the urban centers of the developing world. The depletion of energy resources and the risk of climate change are demanding for a sustainable development path based on renewable energies and energy efficiency [2]. Climate responsive or solar passive building design can play a significant role in reducing the energy demand of buildings without compromising modern living standards.

The most important function of buildings is to provide shelter with appropriate thermal and visual indoor comfort for its occupants. The comfort level in a building depends upon the designs in combination with the outdoor climate. Design irrespective to climatic conditions means either to create uncomfortable indoor environments or to increase the need for maintaining thermal comfort through artificial means. As our ancestors had fewer technologies available for heating and cooling, vernacular houses are mainly designed to optimize the use of natural resources like the

sun and wind [3–7]. Several studies have proven that better thermal performance can be achieved by passive measures in vernacular architecture [6–9]. The developing world's construction practices until recently were basically grounded onto this knowledge of traditional building techniques. However, modernization together with the need of effective and fast provision of shelters for the increasing population has flooded the market with new building designs, technologies and materials. These are rapidly accepted by users who demand for such designs and express increased thermal comfort expectations. The group of new building professionals does often apply new designs without considering local climate conditions.

Consequently, traditional houses are disappearing and the knowledge about its construction practices is slowly forgotten. Therefore, the need to document this knowledge of traditional constructions practices is evident. Few studies [10–12] have analyzed vernacular architecture from specific locations of Nepal in regard to climate responsiveness. This research is the first comprehensive study on solar passive design features of a large number of vernacular houses from all over the country. Following the principle “Learning from the past” [13], it might be the groundwork to develop new and more sustainable design strategies for the fast growing building sector that consider the local climatic conditions while aiming at the reduction of energy-intensive and expensive artificial means to provide comfort.

* Corresponding author. Tel.: +49 32221782489.

E-mail addresses: susanne.bodach@gmail.de (S. Bodach), w.lang@tum.de (W. Lang), johannes.hamhaber@fh-koeln.de (J. Hamhaber).

2. Methodology and structure

Besides the climatic variations in Nepal, diversity of culture has led to a large range of different architectural expressions that are mostly documented by anthropologists, ethnologists and architects [14–21]. This research is based on a literature review and field research in Nepal.

In a first step, the paper gives an overview of the research country Nepal focusing on aspects that are most relevant for the development of vernacular architecture such as cultural and geographical diversity, local materials and climate.

Secondly, the climate conditions in Nepal are investigated, based on climate data from four weather stations that are representing the most important climatic zones of the country. The study identifies the dominating bioclimatic design strategies for the four predominant climates using three tools: Olgyay's bioclimatic chart [3], Givoni's psychrometric chart [4] and Mahoney Table [5]. Olgyay's bioclimatic chart is based on the outdoor climate factors considering humidity versus temperature [3]. Monthly data of minimum and maximum relative humidity and temperature are plotted onto the chart for each month. If the plotted line falls within the comfort zone, conditions are comfortable in the shade and in still air. If the line falls partly or totally outside of the comfort zone, corrective measures are necessary such as the use of solar radiation, air movement or evaporative cooling [3]. Givoni uses the psychrometric chart for the bioclimatic analysis [4]. A psychrometric chart is a graph of the thermodynamic parameters of moist air at a constant pressure. Givoni's chart predicts the comfort conditions within the building based on outside climate factor. As in Olgyay's chart the combination of monthly temperature and relative humidity indicates the recommended passive design strategy for each month. The chart contains the comfort zone, marked by a solid line and several zones for passive design strategies, namely passive solar heating, humidification, evaporative cooling, natural ventilation, and high thermal mass [4]. The Mahoney Table methodology is a set of reference tables that use monthly climate data of temperature, relative humidity and precipitation to calculate indicators for heat and cold stress as well as humid and arid conditions for each month. The combination of these indicators results into simple design recommendation, e.g. "reduce sun exposure", "compact building layout" or "medium sized openings" [5].

In the third step, this research analyses a variety of vernacular houses in Nepal, located in different climatic zones, in respect to their design and construction in order to determine the applied climate-responsive design strategies. For the analysis of traditional housing the approach of [22,23] was adapted. Both studies use a set of building features to analyze the design and construction techniques of the vernacular buildings in regard to climate-responsiveness. This research has selected the following features to assess the vernacular houses of Nepal in a qualitative manner: settlement pattern, building form and orientation, building stories and internal space arrangement, design and construction materials of walls, roof, foundation, floors, ceilings and openings.

Concluding, the study compares the design strategies identified in the second step based on bioclimatic approach with the actually applied strategies in the vernacular houses aiming to prove the hypothesis that traditional houses are very much adapted to the local climate conditions.

3. Research region

3.1. Geographical diversity

Nepal's territory expands about 800 km east–west and 200 km north–south and displays a highly varying topography (Fig. 1).

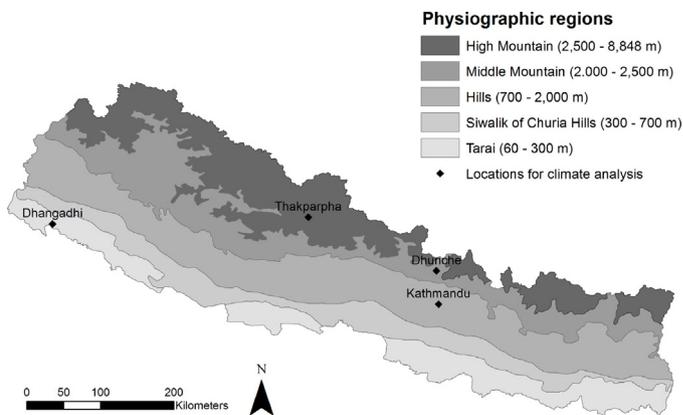


Fig. 1. Physiographic regions of Nepal

Adapted from [38].

Altitude reaches from 65 m.a.s.l. (meters above sea level) to 8848 m.a.s.l. at the Mount Everest, the highest summit of the world. This is leading to a variety of climatic and vegetation zones. Climate has also strongly influenced the traditional architectures. Furthermore, Nepal's population is composed of a large number of different ethnic groups as a result of successive migration of Tibeto-Burman people from the north-east and Indo-Aryans from the south-west [24]. Each ethnic group has its own culture, religious beliefs as well as traditions, and in most cases, also language. Geographical diversity has resulted in diverse socio-economic and cultural patterns and, thus, in a variety of different architectural expressions. Typical houses of a number of ethnic groups (Tharu, Limbu, Newar, Sherpa, Tamang, Thakali, etc.) are analyzed within this study.

3.2. Traditional building materials

The local availability of certain building materials, in particular mineral based materials, depends on the geology of the location. Due to the geodynamic process in the Himalayan region Nepal's geology has a high complexity of many thrusting, faulting, folding and metamorphic effects. Nepal is divided into five distinct morpho-geotectonic zones from south to north: the Tarai Tectonic Zone, the Churia Zone (also called: Siwalik), the Lesser Himalayan Zone, the Higher Himalayan Zone and the Tibetan Tethyan Zone [25]. These five zones comprise a total number of eight geomorphic units which lead to different kind of available materials for building construction (Table 1). On the other hand climatic conditions determine the typical vegetation in a region and, thus, the availability of organic building materials like wood.

The Tarai Region's geology is mainly characterized by coarse, gravel, and finer sediments. Rich fertile alluvial soil is the basis for fertile agricultural land and dense Sal forest. Therefore, traditionally abundant reserves of wood, thatch, and further biogenic material as well as mud and sand are locally available for house construction.

In the Hilly Region of Nepal more stones (schist, phyllite, gneiss, granite, limestone and slate) are available and used as construction material. In larger valleys like Kathmandu lacustrine soil deposits are used for brick making. Sand and gravel is available from the riverbeds. Dense vegetation in the form of Sal or hill forests lead to the wide availability of timber. Fertile land and favorable climate conditions allow for the production of other vegetation based building materials like thatch.

The Himalayan Mountain Region provides abundant resources of stones, rocks and mud. Due to the small availability of fertile land

متن کامل مقاله

دریافت فوری ←

ISIArticles

مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات