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Performance of Vernacular Building in Hot and Humid Climate of Janakpurdham

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Abstract

Nepali art and architecture have become an important part of the country's cultural heritage. Architecture is a term used to describe the art of organizing a living space in Nepali, which is known as Bastukala. Even from a scientific standpoint, Nepal's ancient architecture, such as the art of painting and sculpting, is considered exceptional. The Objective is to find out the performance of the studied vernacular building in Janakpur and measure and depict its performance in terms of the materials used and field data that was collected.The places with hot and humid climate have temperature which ranges from 35°C to 40°C in summer.This study focuses on the aspect for understanding and measuring the performance of vernacular buildings in hot and humid climate of Janakpur. The study analyses the various aspects and evaluates and tables the performance of the vernacular building in Janakpur in exact real condition and the way it is being built. The Climatic data measurements were taken on field and those were taken as the software inputs which is crucial for determining the building performance of the area. The on-site measurements and case study of a building was done in JanakpurDham and the performance with regard to the climate and the data collected on field was used in this research. The discomfort period was found to be maximum in month of May and June to September was also uncomfortable to live in. The Fabric gains suggested that the months in April to June had the most heat gains through envelope resulting in higher discomfort inside. The conduction gains was found to be the main reason of discomfort contributing to 29% of the total building gains and Inter-zonal losses was found to be 58% which was found to be the main reason for winter discomfort in the studied building in Janakpur.Thus, the study helped to find out the building performance of vernacular buildings in Hot and Humid climate of Janakpur and helped us study about the various aspects of building performance in the place.The study also found out that one of the main reasons of winter discomfort was due to the lack of air tightness and an open-space type of planning in vernacular architecture in the studied building in Janakpur.

Keywords

Vernacular Buildings, Janakpur, Hot and Humid Climate, Building Performance, Ecotect

1. Introduction

Nepali art and architecture have become an important part of the country's cultural heritage. Architecture is a term used to describe the art of organizing a living space in Nepali, which is known as Bastukala. Even from a scientific standpoint, Nepal's ancient architecture, such as the art of painting and sculpting, is considered exceptional.

Nepalese architecture is also regarded as one of the nation's most important cultural heritage arts. The ancient architecture is impressive for its mastery of craftsmanship and chiseling techniques. The heritage and architectural structure bear witness to the Middle Ages' efforts. Art and architecture are important in Nepal because they reflect the country's ancient history and diverse lifestyles. Art and architecture are cultural and traditional identities of people and races. Nepal has always been valued for its beautiful cultural artifacts, chariot festivals, culture, ethnic groups, religions, and way of life, and the architectural values and arts that trace this region can be used to humanize the civilization. Nepalese civilization has been linked to Buddhism and Hinduism at times. The Tibetan Plateau and the Indian subcontinent have had a significant influence on Nepali culture, resulting in the development of art and architecture.

The Hindu faith is practiced by the majority of the population, and Hinduism and Buddhist philosophy have influenced Nepalese rulers since ancient times. In Nepal, the shadow can be seen in architectural structures and monuments. Nepalese art is exemplified by Hindu deity art, thangka paintings, temple architecture, and chaityas.

Because Nepal was once a Hindu country with a large Hindu and Buddhist population, Muslim and Christian influenced architecture is uncommon. And, because Nepal has never been ruled by a Muslim or Christian king, the Hindu and Buddhist influences on Nepalese art and architecture may be explained.

The goal is to determine the performance of vernacular buildings in Janakpur and to measure and depict it in terms of materials used and field data collected.

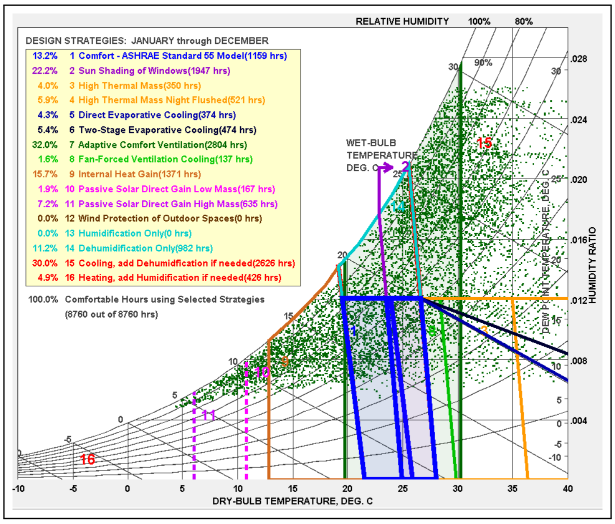

Figure 1: Bioclimatic Chart of Janakpur (As extracted from Climate Consultant Software)

2. Methodology

For measuring the performance of the vernacular buildings first the bioclimatic chart of the selected place was studied and the studying the climate and then draw out conclusions according to the historical climate and software outputs.Therefore , the historical climate of the study location was studied in order to determine the details of energy performance in that location.

A questionnaire survey was carried out for studying about the construction materials used , the energy consumption pattern which provided the necessary information for the inputs regarding the software simulation.

2.1 Climatic Analysis

A bioclimatic chart is a preliminary analysis tool used during the early stages of a construction project. Its goal is to identify desirable structural adaptations to meet human comfort needs under specific climatological conditions [1]. That is, the bioclimatic chart would indicate a thermal comfort zone where no cooling or heating is required. To reduce energy consumption, simple building techniques and methods such as incorporating natural cooling systems and techniques, passive solar heating systems, and natural lighting systems and techniques can be applied to buildings using the chart [1]. Below is an example of bioclimatic chart by Givoni which shows various zones.

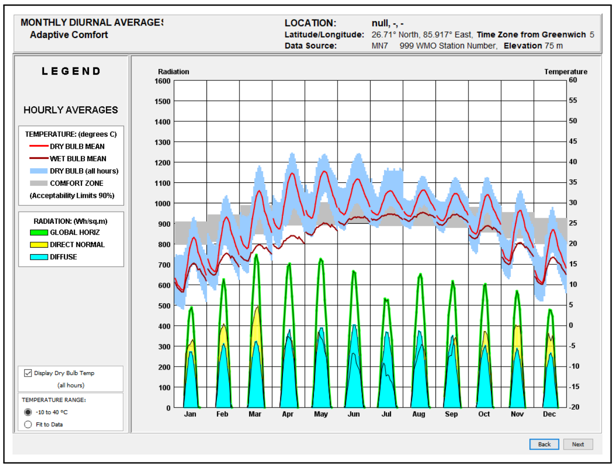

Figure 2: Daily Diurnal Average Temperatures - Monthly (As extracted Climate Consultant Software)

3. Literature Review

In hot and humid climates, vernacular architecture is mostly made of low-mass materials like wood. Because the indoor temperature drops rapidly at night, these buildings are deemed suitable for this climate [2]. Building functions have evolved over time. While buildings were once designed primarily to protect against the sun, wind, and rain, their functional requirements have evolved significantly. People spend the majority of their time in buildings that require thermal comfort in all seasons and at all times, so many activities take place in buildings that require a controlled environment.

Building thermal performance and thermal comfort are frequently confused when the former defines the latter's scenario. In this context, building thermal performance is defined as the building's ability to maintain a comfortable indoor climate with minimal energy demand regardless of the outdoor climate scenario, and thermal comfort is an expression of satisfaction with the thermal environment [3]. Due to irregularities in building construction geometry, materials used, and cultural differences, it is difficult to define or generalize the thermal performance of Nepalese buildings, but when indoor operating temperature and building relative humidity are considered, a comfort perspective can be drawn in the accommodation [4]. The Passive House design parameters assisted in reducing the energy demand of a typical house by nearly 50%. A comparable result was discovered for the performance analysis of 24 hours with cooling during the hot season.

This result indicates that nearly 50% of energy can be saved while maintaining thermal comfort inside the building during both hot and cold seasons [5], and understanding the performance of the building is critical. According to the International Energy Agency (IEA), global greenhouse gas emissions are rapidly increasing, and it will be difficult to limit the long-term rise in global average temperature to 2°C below pre-industrial levels [6]. As a result, by conserving energy and maximizing the use of renewable energy, the construction sector can play an important role in mitigating the effects of climate change.

4. Context of Study

4.1 Vernacular Buildings in Janakpur

Traditional vernacular architecture is a wonderful legacy left to us by our forefathers. This technology has been in use for many years with few environmental or health consequences. The buildings are well suited to their surroundings, taking advantage of local building materials and techniques. We feel very relaxed and comfortable in the ambient spiritual atmosphere of traditional architecture from various parts of the world. People travel to various parts of the world to see and experience their natural beauty. We must pass on this feeling to future generations so that they can learn from it and understand the importance of conservation.

The vernacular buildings in Janakpur that were built in the past carried with them a blend of history, culture, and tradition. Traditional houses are typically rectangular in shape and three stories tall, with the top floor enclosed by large pitched roofs. In rural areas, they are raised to a 450mm pedestal to prevent water ingress. To keep the sleeping and storage areas above warm, the kitchen and livestock are housed on the ground floor. Porches serve as outdoor living and working spaces. In cities, the ground floor of a timber-frame basement often houses a shop or workspace. The construction of houses varies depending on the available local material resources, geography, and climate.

In Janakpur, the houses are of masonry construction interlocked with wood and brick. To keep the heat at bay, windows are typically small and walls are thick. Clay and clay tile roofs also provide insulation against the elements. The walls are protected from torrential rain by sloping roofs and wide eaves; exterior wall surfaces are regularly applied with fibre mud plaster to keep them watertight; and drains remove water from the foundations. As a result, the buildings are well-designed for cold winters and wet summers, while also providing the necessities for daily living in a confined space.

The vernacular buildings and their typical methods of construction that has been used since past and has been taken over seems to have a reason associated to climate of the place and which has been studied in this research. The clear connection of these buildings with their way of construction and energy performance seems interesting aspect to be looked after.

4.2 Construction Technology

The construction technology which has been used in the past were mostly made of bamboo frames supported with mud and lime mortar or lime-mud mortar etc. supported by roofs made of up of hay or clay tiles and Khapada (locally called). The houses had plinth raised by bricks and thick mud slab reinforced by hay or rice husk etc to create a thermal mass and insulation at the same time which kept the interior spaces cold enough even in the high summer heat. The buildings didn't have much openings, and used narrow openings or no openings at all. Some houses used a circular kind of ventilation window, which worked both for the air circulation and also created the stack ventilation effect.

Figure 3: Case building - Typical Vernacular House

4.3 Energy Use

The energy use and behaviour in the vernacular buildings in Nepal show us that most of the houses used only the candles and lanterns as source of light in the past. Although , access to grid electricity has been facilitated in all the regions , the connection seemed to be scarce due to various reasons. The use of firewood, cattledung for cooking and burning purposes are still prevalent in the area. There were still many houses which did not had the connection to electricity at all. The vernacular buildings mostly used the natural fuels and energy sources for their day to day activities and were mostly reliant on those sources for which they won't pay or don't have to pay much in relation to the economic status of majority living here.

4.4 Society and People

Janakpur Municipality had 19,195 households and a population of 98,446 people in June 2011, with a population density of 4,000 people per square km. It was designated a sub-metropolitan city in 2015, encompassing 11 surrounding cities. With a current population of 173,924 people, it is Nepal's sixth largest city.

Maithili is widely spoken as a mother tongue in the region and is also used as a native local language. Nepali, Hindi, Marwari, and English are widely spoken. Languages such as Bhojpuri and Awadhi are understood but rarely used. More than 90% of the population is Hindu, with the remainder being Muslim and Buddhist.

4.5 Economical Aspect

Janakpur is Nepal's fastest growing city and the country's largest sub-metropolitan city. The city has excellent health-care facilities, as well as a number of parks, private schools, universities, and internet service providers.Tourism, agriculture, and local industry are the mainstays of the economy. Mithila art refers to Maithili women's ceramic, wall, and terrace paintings.

Janakpur attracts immigrants from the surrounding area looking for healthcare, education, and employment. Janakpur Cigarette Factory Limited and Janakpur Railway were the main employers until they were closed down in 2013 due to political corruption and large loans. Service was restored in late 2018. Zone Police, Zone Hospital and Banking Sector help locals live relatively easy lives. The city has many commercial banks and private banks, government banks to cater the needs for running economy of the place.

4.6 Geography and Climate

Janakpur is in southern Nepal, between latitudes 24°-20'-10"N 27°-31'-15"N and longitudes 83°-19'-50"E 88°-17'-40"E. It is a fully closed state in the temperate zone's subtropical region. Winter temperatures in Janakpur range between 0 and 10 degrees Celsius (32 to 50 degrees Fahrenheit). December and January are the winter months. Summer temperatures range from 35 to 45 degrees Celsius on average (95 to 105 Fahrenheit). The hot months are from April to mid-June. Rainfall is abundant during the monsoon months of June, July, August, and September.

The months of October and November, as well as February and March, have pleasant weather. The tropical region has an unpleasant climate with excessive solar exposure, high temperatures, moderate relative humidity, and long sunny days all year.

5. Energy Modelling and Findings

5.1 Energy Modelling

The process of creating computer models of energy systems for analysis is known as energy modeling. A virtual computer simulation of a building or complex that focuses on the energy consumption and life cycle costs of various energy-related elements such as HVAC, lighting, and hot water is known as energy modeling (Extergy, undated). Building energy modeling is a common tool that engineers can use to mathematically model the performance of a building over time in order to understand its potential energy use.

The Autodesk® Ecotect® Analysis for Sustainable Design Analysis software is a comprehensive tool for designing sustainable buildings from concept to detail [7]. Ecotect Analysis offers a comprehensive set of building energy analysis and simulation capabilities that can improve the performance of both existing and new building designs. Autodesk Ecotect Analysis is an environmental analysis tool that allows designers to simulate building performance from the concept design stage. It combines analysis functions with an interactive display that shows the results of the analysis directly in the context of the building model.

In this study, Ecotect Simulation Software was used to understand the building performance of the study area. The results of the analysis can be mapped onto building surfaces or displayed directly in the spaces that generated them, providing us with the best opportunity to understand exactly how the building is performing.

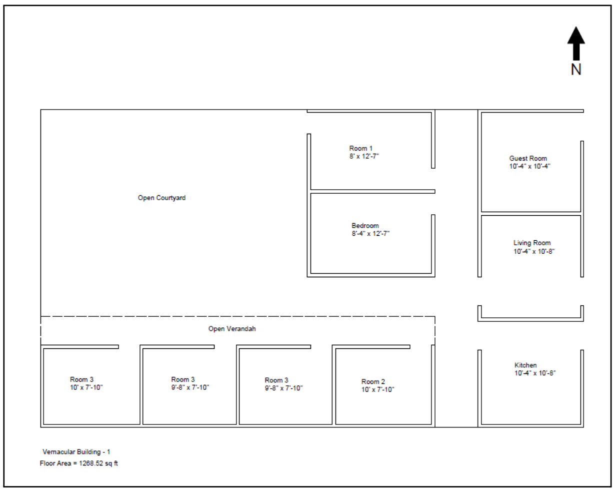

Figure 4: Floor Plan of studied vernacular building

This is the plan of the building which was studied in Janakpur it shows the type of space planning that is generally done in the typical vernacular buildings.

5.2 Construction Materials

The construction materials that were identified on site are shown below and listed which were used later in the simulation as software inputs for materials of the case building.

Building Components	Vernacular – Base Case
Walls	2” Bamboo Frames + 1” Mud Plaster on both sides
Window	N/A
Door	Solid Core Timber
Floor	(Thick Mud + Hay) layer on flat brick soling
Roof	Clay Tiles on bamboo supported frames (Pitched Roof - Two way slope)

Figure 5: Construction Materials

5.3 Software Inputs

The software inputs are the parameters that were found out on field and which will be used in the simulation to replicate the exact real conditions as on site to that on computer so that we get the identical results from the simulation as that of studied in the site area.

Software Inputs	Vernacular Building
No. of Occupancy	7 People
Humidity	60% (Indoor)
Infiltration Rate	1.0 ACH (Average)
Air Speed	0.1m/s (Not Noticeable)
Type of System	Natural Ventilation
Thermal Comfort Range	18°C - 28°C

Figure 6: Software Inputs

5.4 Results

The energy analysis from Ecotect was done and the results were obtained which includes the various aspects of energy analysis related to the building performance and the results are shown in this section.

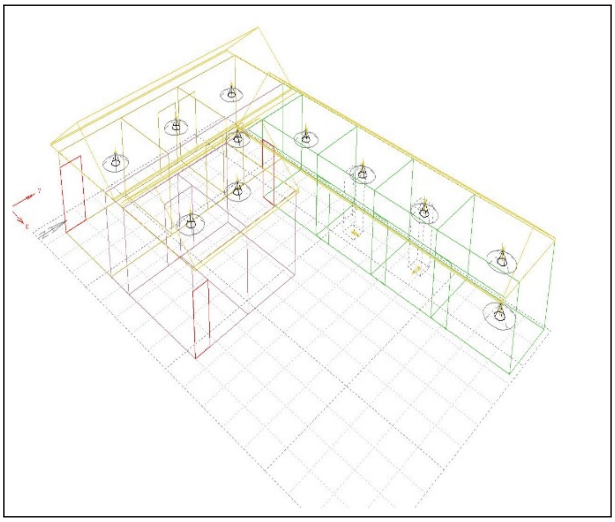

Figure 7: Energy Model - Typical Vernacular House

This is the energy model used in the software Ecotect for carrying out simulation and for finding out the performance of traditional vernacular building performance by using the materials that were used for constructing the building.

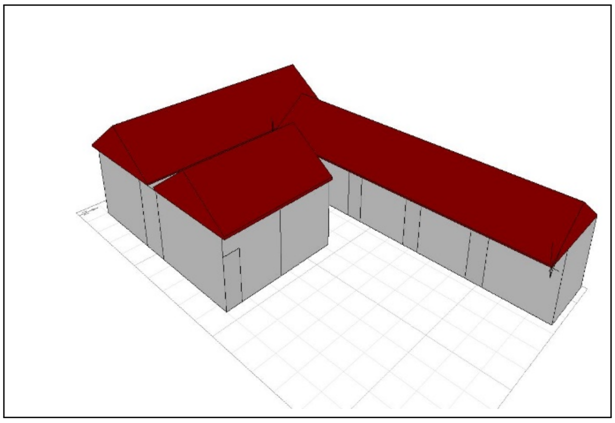

Figure 8: Visualising the Energy Model for verncular building

5.4.1 Thermal Discomfort

The monthly discomfort periods for given range shows total hours the occupants will feel too hot or too cold depending on the outside and inside conditions during various times of year. The data shows that May is the most uncomfortable month to live in that climate along with June – Sep being uncomfortable months to live in as well .

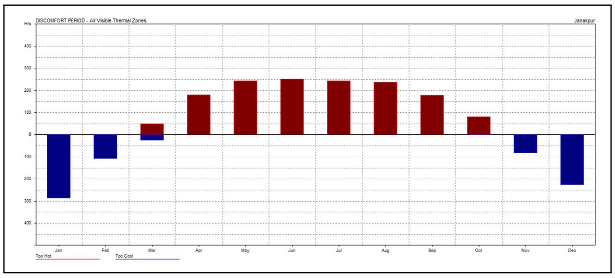

Figure 9: Thermal Discomfort Periods in studied building

5.4.2 Fabric Gains

The Fabric Gains suggests that for the vernacular building studied the max gains reached upto 7000 Watts in the months April- Jun making the inside of the building hot and uncomfortable.

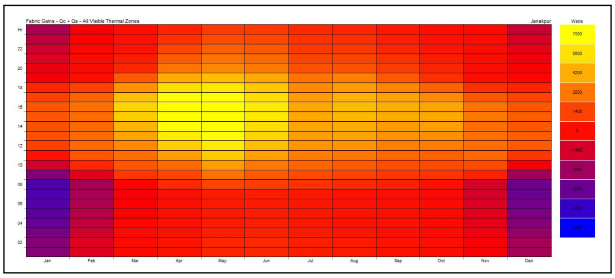

Figure 10: Fabric Gains Analysis in studied building

5.4.3 Passive Gains Breakdown

The Passive Gains breakdown shows that out of all the gains in the vernacular building was maximum for the conduction gains for about 29% followed by Sol-air gains which contributed to about 22% among all other gains. Similarly, the maximum losses were due to the Inter-zonal losses of about 58% as the building plan suggests open type of detached building plans followed by Conduction losses which accounted to about 35% of the total losses.

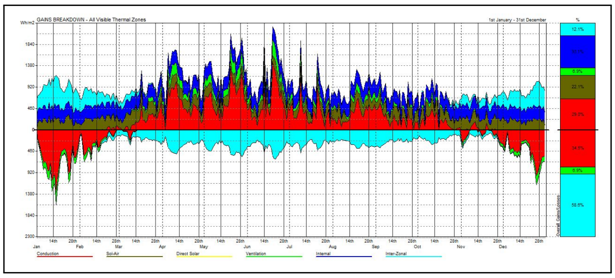

Figure 11: Passive Gains Analysis in studied building

5.4.4 Temperature/Gains Comparison

The Temp/Gains comparison shows us that for the vernacular building the maximum gains and losses occurred as per square meter of the building which has accounted to about 120 Wh/m2 gains and about 60 Wh/m2 as losses for the building envelope.

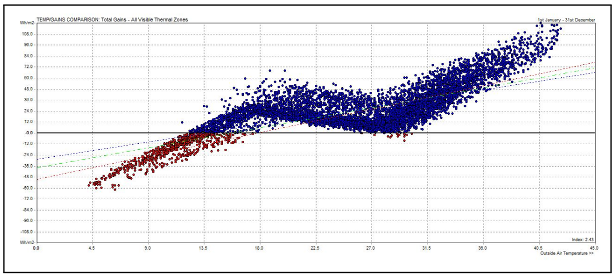

Figure 12: Temperature/Gains comparison in studied building

5.4.5 Cummulative Energy Use

The Cummulative Energy consumption shows the amount of energy consumed or used by the vernacular building over the year and it was found to be about 720 KW-h per year from the software and was field verified by manual calculation as well.

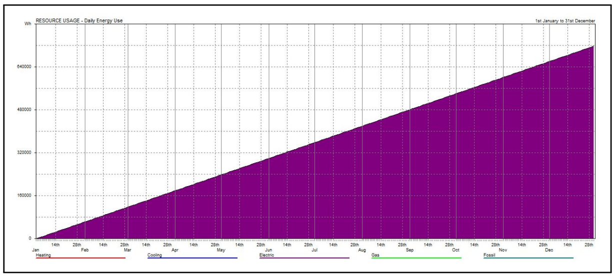

Figure 13: Cummulative Energy Use in studied building

6. Conclusions

A key objective was to achieve a comparative assessment regarding various aspects of energy performance which has been carried out for the studied case building. The research has a firm orientation to existing construction practices and can give the readers an idea of what to expect from the vernacular buildings that have been constructed in the past and their performance.The findings suggested the discomfort period was found to be maximum in month of May and June to September was also uncomfortable to live in. The Fabric gains suggested that the months in April to June had the most amount of heat gains through envelope resulting in higher discomfort inside. The conduction gains through building components was found to be the main reason of discomfort contributing to 29% of the total building gains and Inter-zonal losses was found to be 58% which was found to be the main reason for winter discomfort in the building.

Two major environmental factors, air temperature and relative humidity, have a direct impact on thermal comfort and can be considered key components in energy performance analysis. After measuring the building energy performance of the vernacular type of building in Janakpur, We can certainly get a head start on passive design methods for buildings, which are one of the energy efficient design principles that help the building consume less artificial energy. It contributes to energy conservation and the reduction of global warming. It reduces the duration of the building's overheated period, as well as its reliance on air conditioners and other electromechanical devices. Architects and engineers can use such techniques in new construction as well as when modifying and retrofitting older structures.

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