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Thermal Performance of Nepalese Building- A Case Study of Dhulikhel and Biratnagar

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Abstract:
Nepal has wide variation in altitude, so does its climate, lifestyle and housing. The building design code issued by the Government of Nepal does not address the issue of thermal comfort, which could be the reason the modern buildings built under the design code are performing poorly in terms of indoor thermal comfort. As a result, people have largely compromised in accommodation. The research includes selection of two representative buildings (at Biratnagar and Dhulikhel) followed by real time monitoring of indoor climate (temperature and Relative humidity). The logged data was used to calibrate the computer model. The model was approximated to real scenario including indoor heat loads from people, lighting, electric equipment and infiltration. Building energy modeling was done in EnergyPlus. The research work depicts the thermal performance of building by comparing the indoor climate of selected buildings of Biratnagar and Dhulikhel with the ASHARE suggested thermal comfort level for humans. The major problem found in the buildings of Biratnagar was overheating for more than 6 months period while for Dhulikhel was under heating for more than 4 months period. The author suggests further research to analyze passive techniques to improve thermal performance and reduce active energy consumption.

Keywords: Thermal Comfort, Building Design Code, Indoor Climate

1 Introduction

Nepal has a wide variation in altitude, so does its climate, lifestyle and housing. Nepal is enriched with diverse building and housing practices. [1] The building practices are related to the country's economy, per capita income, culture, tradition and people's lifestyle. Besides, the housing practices can be also categorized based on altitude belts and climate zones. Mostly, residential buildings in the high hill region are of SMM type. BMM and BMC type buildings are found in the mid-hills and Terai belt of Nepal. Similarly, bamboo and wood-based structures are also found in the Terai belt [1].

The study location Dhulikhel is located in the mid-hill region of Nepal, 30 km east of Kathmandu at an altitude of 1500 meters from sea level. Similarly, the other study location, Biratnagar lies in the south-east region in the Terai belt of Nepal. In both the study location, BMC type building occupy the major part of residential building. Thermal performance of building and thermal comfort often come together as the first defines the scenario of the other. Thermal performance of building in this context is seen as the ability of building to maintain comfortable indoor environment with minimal energy demand regardless of the outdoor weather scenario and thermal comfort is the expression of satisfaction with the thermal environment [2]. Most European and western countries have specific set of guidelines of indoor environment to achieve indoor thermal comfort. Nepal however, lacks such practice.

In Nepalese context, the adaptation to the indoor climate by bringing variation in clothing and food habits [2] makes the residents unaware about the poor thermal performance of their building. From general observation alone, the status of thermal performance of the building can be perceived but the extent of discomfort caused by the poor thermal performance however still remains a query. This research work aims to quantify the extent of this discomfort.

It is difficult to define or generalize the thermal performance of Nepalese building due to the irregularities in building construction geometry, materials used and cultural differences but if considered the indoor operative temperature and relative humidity levels in the building, perspective of comfort in accommodation can be drawn [3]. The quantification of this comfort level is possible through energy modelling of the building.

Nomenclature

BMM	Brick Masonry in Mud Mortar
BMC	Brick Masonry in Cement Mortar
SMM	Stone Masonry in Mud Mortar
ASHRAE	American Society of Heating Refrigeration and Air Conditioning Engineers
CAD	Computer Aided Design
TEC	The Energy Conservatory Inc.
EEBDT	Energy Efficient Building Design Technology

1.1 Statement of Problem

To address the issue of thermal comfort in accommodation, the current practice is by either direct heating of biomass or using sophisticated HVAC systems.

The Government of Nepal has directions for the building design code for Nepal, but the design is incomplete if viewed form the thermal aspect of the building [4]. The building design code does not address the thermal comfort. As a result, people have largely compromised in comfortable accommodation.

The increasing demand of energy for building heating and cooling requirement [5], people depending on clothing and food habits to thermally adjust in harsh weather [2], all this clearly hints towards poor thermal performance of Nepalese Building. Since, the study on thermal performance of building is rare, there is no clear picture of present scenario of thermal performance of Nepalese buildings.

1.2 Aim of the paper

The aim of this paper is to quantify the thermal performance of Nepalese Building (Case study of Building at Dhulikhel and Biratnagar) by making a viable comparison of indoor temperature and relative humidity data with ASHARE suggested comfortable range.

2 Research Setup and Methodology

The study uses simulation tool namely Energy Plus to perform energy modelling of the building. The CAD model of the building was drawn in SketchUp with aid of SketchUp OpenStudio Plugin. The indoor temperature and relative humidity were monitored in real time using HOBO MX2301 data loggers for a month period to later validate with the simulated data. The building infiltration was measured using standard TEC Minneapolis Blower Door setup. The picture of thermal performance of Nepalese building is then drawn by comparing the temperature and relative humidity profiles with ASHRAE suggested thermal comfort levels.

Two buildings, one from Dhulikhel and one from Biratnagar was selected for study. Both the building was of Brick Masonry in Cement Mortar type construction. Further details on building geometry, construction characteristics are mentioned below.

2.1 Building Detail

Table 1 shows the material description and layer wise construction definition for the studied buildings.

Table 1: Building Construction Specification

Construction	Layer (Outside-Inside)	Layer Name
Wall	1	Plaster 15mm
	2	Brick 228.6mm
	3	Plaster 15mm
Roof	1	Concrete 100mm
	2	Plaster 15mm
Ceiling	1	Concrete 100mm
Door	1	Wooden Plank 25mm
Window	1	Glazed 6mm clear glass
Floor	1	Concrete 100mm
	2	Plaster 15mm

2.2 Thermal Zone and Load Description

2.2.1 Biratnagar

Figure 1 shows the CAD model of the studied building of Biratnagar. The purple cuboids represent the neighboring buildings at the site. The monitored thermal zone of the building has a total occupancy of 6 people with real time schedule of their presence in the room and activity level made for simulation. The zone has constant infiltration of 1.2ACH, lighting power of 20W and Television (90W) and Fan (60W) are run at scheduled time period.

2.2.2 Dhulikhel

The monitored thermal zone of the building has a total occupancy of 2 people with real time schedule of their presence in the room and activity level. The zone has lighting power of 20W and Laptop (50W) are run at scheduled time period. The CAD model of the studied building is shown in figure 2.

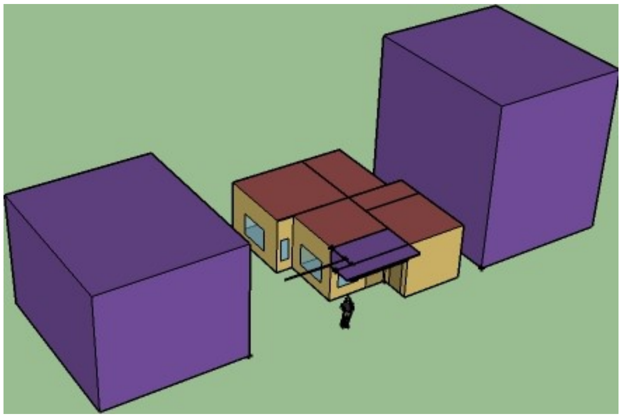

Figure 1: CAD model of Building

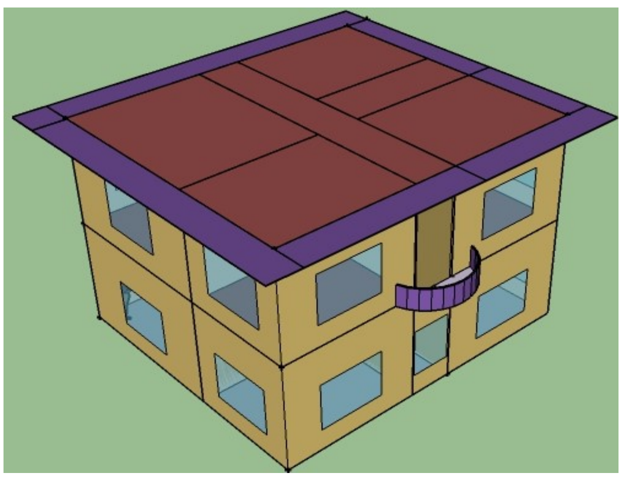

Figure 2: CAD model of Dhulikhel Building

3 Result and Discussions

The ASHRAE Standard 55-2004 recommends a temperature range of 20°C to 24°C in winter season and 24°C to 26°C in summer season with indoor air relative humidity of 50% as thermally comfortable range for humans. ASHRAE also recommends relative humidity to not exceed 65% and fall below 30% [6].

The thermal performance of selected building was observed for a year period considering mainly the indoor temperature and relative humidity.

3.1 Results from Biratnagar Building

The indoor temperature ranges in number of hours of a year is shown in Figure 3. The green bars represent the thermally comfortable temperature range as suggested by ASHRAE. Red columns represent temperature outside the comfortable range. Figure 3 shows that more than 4800 hours of the year (i.e. more than 6.5 months) the indoor temperature is higher than 28°C which is thermally uncomfortable range for humans. The figure shows that the comfortable range is only about 5 months in total in a year.

The study of indoor temperature and relative humidity results over the year showed that indoor temperature reaches as high as 38°C and low to 16°C with the average relative humidity level around 65% which is numerically within the ASHRAE suggested humidity level but that the number of hours spent in uncomfortable range of humidity level is higher than 4 months in a year.

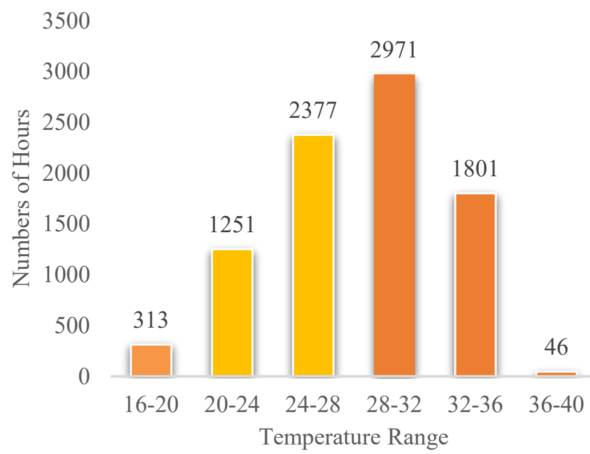

Figure 3: Numbers of Hours in specific temperature range for Biratnagar building

3.2 Results from Dhulikhel

Building energy modeling was performed for the building of Dhulikhel. The indoor temperature ranges in number of hours of a year for the studied building is shown in figure 4. The study shows indoor temperature falling as low as 7°C in months of December-January and reaching as high as 33°C. Figure 4 shows that almost for a month period the temperature is higher than 28°C and for almost 5 months period the temperature is below 20°C and reaching as low as 7°C. The total periods of comfortable indoor environment were accounted only to about 5 and half months. Relative humidity data shows humidity level falling below 45% for almost 4months and reaching higher than 65% for almost 2 months period.

3.3 Discussion

The author used the real time logged indoor temperature and relative humidity data from the studied buildings to calibrate and verify the simulation model.

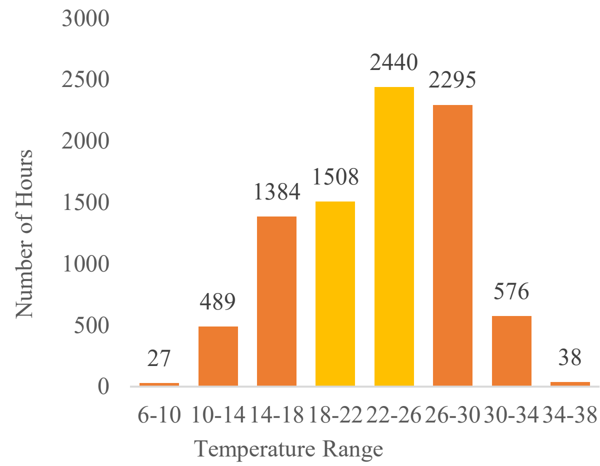

Figure 4: Number of Hours versus Temperature Range for Dhulikhel Building

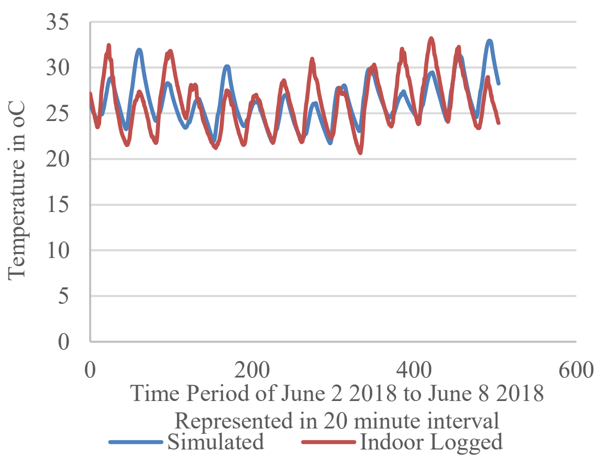

Figure 5: Simulated versus Logged Indoor Temperature graph

Figure 5 shows comparative graph of the logged and simulated indoor temperature for Dhulikhel building. The difference between the two readings on hourly temperature scale is less than 8% which validates the appropriateness of the building model used for simulation.

The authors also looked for the potential heat gain and heat loss areas that are contributing to the present scenario of discomfort and found out that infiltration alone accounted for nearly 30% of the thermal load of buildings. For building of Biratnagar, the direct heat gain from the flat roof surface was one of the causes of overheating of the indoor space. For the building of Dhulikhel, single glazed window and infiltration was found to contribute to the heating demand.

The results depict poor thermal performance of buildings. The indoor environment is not suitable for accommodation for most of the months in a year. In spite of this, people are still residing with the same housing practice. The biggest question the authors thus find is, **has the occupants really adapted to the present scenario of indoor environment and hence feel comfortable?** Or, **are they compromising with the present scenario because they believe there's nothing, they can do about it?**

The authors believe that the answers to this question will help understand the dynamics of indoor thermal comfort in Nepalese building and will guide to take appropriate measures to make the building thermally comfortable.

4 Conclusion

Building energy modeling of the BMC type buildings of Biratnagar and Dhulikhel was performed and indoor temperature and relative humidity variations were studied to quantify the thermal performance of Nepalese buildings. The study shows that BMC type buildings of Biratnagar gets uncomfortably hot during summer seasons and more than 6 months in a year the indoor space is uncomfortable for human accommodation when compared to the ASHRAE guideline. The study also showed that BMC type buildings of Dhulikhel are under heated thus resulting in cold indoor space for most of the months.

The quantification by number of hours spent by occupants in uncomfortable indoor temperature range proves that Nepalese building in its present state is not thermally comfortable for accommodation as per the guideline of ASHRAE.

Poor airtightness of building was found to account for nearly 30% of the thermal load thus appropriate measures to make the building airtight would help achieve indoor thermal comfort and reduce the energy demand which otherwise would be used same purpose of indoor thermal comfort.

Direct heat gains from the flat roofs in building of Biratnagar was one of the causes of overheating of indoor space thus designing attic spaces or actions to avoid direct heat gain via roofs would increase indoor comfort.

The author believes that this research will pave a way for further researches to be conducted to improve performance of building by analyzing different passive heating and cooling strategies for Nepalese houses such that people will get to live in comfortable indoor climate and also help reduce energy consumption.

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