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Thermal Comfort Performance in a Residential Building of Subtropical Climate of Nepal - A Case Study of Hetauda

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Abstract

The thermal sense of the environment is referred to as thermal comfort. Thermal comfort is influenced by two main environmental variables, including air temperature and relative humidity. Up to 90 percent of people's time is spent inside of buildings. Buildings should therefore take into account the bioclimatic conditions of the location where they are built in order to raise the living standards of their inhabitants. Today's Modern residential buildings in the country are designed and built without considering climatic factors. The study area is carried out in Hetauda Padam pokhari Sub-metropolitan in the Makwanpur District of Bagmati Province in central Nepal.The main objective is to assess thermal performance for thermal comfort of modern residential buildings of Hetauda incorporating its improvement in design strategies for thermal comfort with comparison with modern residential building with other types of building in terms of U-value, materials, temperature etc. This research adopts the pragmatic paradigm. The objective set lead towards quantitative research as well as a qualitative research method. The indoor and outdoor temperature of the different nine types of the residential house like modern, hybrid and traditional residential building of Padampokhari for 7 days summer has been collected in the field, which has been compared with each other investigated houses of case area The summer comfort temperature of padampokhari, Hetauda has been calculated using Nicol's adaptive thermal comfort model, which has been also compared with the assessed temperature of investigated residential house. The findings based on calculations and regression analysis shows that the investigated traditional residential house maintains 1-2.2℃ indoor temperature in summer. Finally proposed design strategies for the newly constructed modern residential building has been suggested according bioclimatic chart and Mahoney table and recommendations at different levels has been provided for future study.

Keywords

Thermal comfort, residential buildings, subtropical region, Air temperature, Humidity

1. Introduction

The thermal performances of a building are ruled by the factors like climatic condition, geographical location, material availability, lifestyle, and socio-cultural activities. Usually, as seen traditional houses are performing well in this context than modern houses. There were many types of research speak about building performs better thermal environment than contemporary buildings [1]. When designing metropolitan areas and estimating how much energy is required to cool and heat buildings, thermal comfort is important. The idea of thermal comfort is ”that state of consciousness that conveys happiness with the thermal environment” [2]. According to ASHRAE (America society of heating, refrigerating and air conditioning engineers) it mainly focused in the 4 point for inner thermal comfort in a building 4 points are visual comfort, air quantity, noise level and thermal comfort which is mainly studied in this area, this is the most well studied factor, and it depends on a number of characteristics, including humidity, air conditioning temperature, outside temperature, and air speed, rather than just one. Because most people spend up to 90 percent of their time indoors, the state of their indoor settings has a significant impact on how well they live [3]. Therefore, in order to raise the living standards of those who inhabit them, buildings should take into account the bioclimatic conditions of the area in which they are located [4]. One of the best way is Climate responsive design strategy performance good to achieve thermal comfort as it consumes less energy and proves economical in long run.

Residential Buildings are essential to society because they house the majority of the activities that individual's do, which direct consequences for both occupant health and energy consumption. Building room with good thermal comfort always improves the standard of life. According to studies done in 1987 by Altman and Stokol, when a room's temperature and humidity are high, workers' productivity in factories or offices consistently suffers. Yet consistent with in 1989, Edward realized that the value of staff pay and business development was significantly less costly than investment and maintenance costs to achieve thermal comfort. So for the great health and healthier lifetime of building as an architect always concentrate on the comfort of the client. There are several studies on the thermal performance of homes within the subtropical climate in Nepal but not in Hetauda city. The influence of modern building materials and construction technology is declining the thermal comfort performance of modern residential buildings. The use of less efficient modern materials and construction technology in comparison to traditional materials and construction technology resulted in the loss of thermal comfort performance of the modern residential building as well as declining the vernacular architecture of any place [5].So the research is needed to assess the thermal performance of all types of building in the site area to compare and analyze the effectiveness of materials that contribute to maintaining the thermal comfort performance inside the residential building.

The research has provided the current situation of construction and materials used in the modern residential building in the case area. Research also helps to know about that how people are using modern materials for construction and the drawback and goodness of materials. The research also compares the thermal comfort performance of the modern residential building with other types of residential building in case areas which help to strengthen the importance of the use of local materials which help to make building climate-responsive and more ecological in the society. The modern construction and design techniques of building homes have been widely accepted but modern architecture has not been clearly defined.

Scope of the researcher is to find out the air temperature, the humidity of the different types of a residential buildings in the case area. It also helps to know about the thermal performance of different types of a residential buildings in the case area. It helps to provide the different design strategies which can be used in upcoming modern residential buildings. The findings and results are limited to the investigated residential building which really does not generalize all the settlement residential buildings in the case area. Indoor and outdoor air temperature for summer and the rainy season is taken using a room thermometer.

2. Literature study

Thermal performance for Thermal comfort is a thermal balance for human body. According to ASHRAE the comfort or standard room temperature is 20°c ±2°c [1].Here in Hetauda, the Traditional style of construction has also been influenced by modernism. Traditional construction's beauty and elegance are beginning to be surpassed by RCC construction. Here at the highway axis, aluminum composite panels (ACP) are preferred[6].

The design, planning, and material selection in vernacular architecture are influenced by the socioeconomic, cultural, and climatic factors of various geographic areas. Different construction techniques and materials availability in the region Thermal comfort performance in modern residential building of subtropical climate- case of Hetauda affect the energy performance of vernacular architecture [7].

Building occupancy and operation effects on the thermal performance of the building. Building are considered to be the primary point of contact between the indoor and external environments, making them primarily accountable for the thermal conditions within. Several factors, including the building's shape, orientation, envelope, and shading devices, must be taken into account throughout the planning and construction of the structure [8]. The material characteristics of a building's components are crucial in regulating the heat transmission process. We'll go through the four most crucial thermal properties: thermal conductivity, thermal resistance, thermal transmittance, and density [9].In order to provide comfort and conserve energy, climatic elements might have an impact on the design and operation of a building's envelope. Understanding the general climate of neighboring regions and the micro climate is essential [9]. Climate variables like sun radiation, humidity, pressure, and winds have an impact on a building's thermal performance. Architecture with good thermal comfort is most important qualities of architect. Among many parameters affecting human comfort with in the built space. Poor thermal comfort of the building effects on the efficiency of work people live inside. There is no any fixed standard or recommended ranges for thermal comfort inside the built surface. But some designing help to achieve balance with local climate. Insulation: Efficient insulation is one of the primary requirements to achieve a comfortable inside condition. It helps to reduce the amount of heat gained during the warm season and conserves heat during the cold month. In any construction, good insulation is required, but it is especially crucial in subtropical climes [3]. Overheat can be seen in roof of subtropical region. Using roofing materials with lighter colors that won't heat up as quickly as conventional black asphalt shingles, like terracotta shingles. Metal siding and roofing offer excellent protection against wind and moisture damage. Because they offer a layer of shade that shields walls and windows from direct sunlight, porches are popular in the south. The selection of material and structure should be done concerning the location, climate and function. Materials such as brick and stone are used in hot environments for their high thermal inertia to keep the interior cool for a longer period [3].

Passive cooling strategy for thermal comfort in subtropical climate: Passive energy can lower the active energy consumption for room heating and cooling.The greatest way to create a comfortable and energy-efficient interior environment is through passive thermal comfort approaches [10]. The provision of natural ventilation through building orientation with apertures to collect prevailing winds, shading, and optimum building fabric selection all contribute to several cooling benefits. One of the best examples to explain the best thermal performance for thermal comfort passive strategies which can be used in a modern building in modern period is Mato ghar which is located at Budanilkantha, Kathmandu can use some same technology in modern building to achieve the thermal comfort inside the built surface.

3. Objective

1. To assess the thermal performance of residential buildings of Hetauda.
2. To compare the thermal performance of the modern building with other types of houses like the hybrid, traditional residential house in the case area.

4. Methodology

The research has carried using both quantitative and qualitative methodology with the pragmatic paradigm. Perception survey of the people was carried out at site for quantitative method also for comparison. The research has been carried out in padam pokhari, Hetauda with mixed settlement of traditional, modern and hybrid residential buildings. For the qualitative method, air temperature data and compared with existing situation to understand the change over time. Literature of the place were also studied to understand different research indicators like measurement of air temperature, building orientation, thermal transmittance (U-value) of materials used and size of the openings were considered. After selection of indicators the data collection was carried out in the field. The primary data collection included the measurement of air temperature in the field whereas secondary data collection included climatic data of padam pokhari, Hetauda from direct observation of the site, Department of Hydrology and Metrology,(GoN) and demographic/housing data from report of VDC profile of Padam pokhari, Hetauda. Other methods like questionnaires survey, and mobile ethnography has been used.

4.1 Air temperature

Simple room thermometer HTC-2 is used for measuring the temperature of the buildings. To calculate maximum air temperature of summer season nine different types of residential building were selected and room thermometer HTC-2 was used for continuous 7 days i.e. (may 16th- June 23rd) at center of ground floor of each buildings. The thermometer was place at the height of 5 feet from ground for indoor air temperature measurement and the care was taken to avoid direct sunlight for outdoor air temperature measurement. The air temperature data was taken at 3 different times a day i.e., morning 7Am, day 2 pm, and at night 7pm to calculate the maximum air temperature of summer season. The assessed data were calibrated and the results and findings were drawn through calculation and regression analysis. Finally the recommendations at different levels for further works has been suggested.

5. Site and data

To fulfill the research objective, the study area has chosen where settlement have all the types of residential building like modern, hybrid and traditional residential building. Padampokhari, Hetauda is chosen for the case area. The study area is lies from approximately 20 minute way from Hetauda bazar. Factors such as commercialization, rapid population growth, diverse lifestyle, increase in number of modern residential building, availability of modern construction materials and technology have drastically transformed architecture material and technology. For the field data of this research, the chosen site needed to have buildings constructed with modern, hybrid and traditional technique. The sampling method will be a purposive sampling. 3 number of modern, hybrid and traditional residential building has been selected for the research.

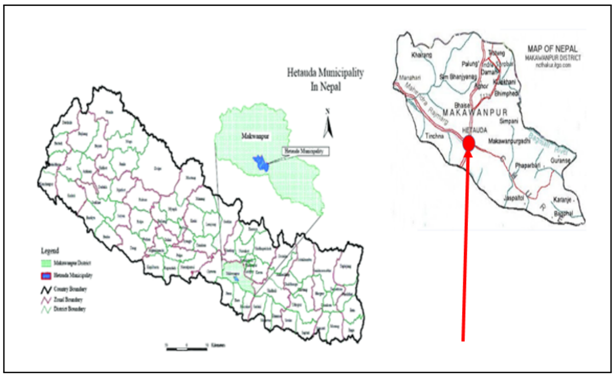


Figure 1: study area,source: Google.com

5.1 Climate of Hetauda

The below figures show Nicol Graphs for Padam pokhari which start finding the temperature in which people find comfortable to live, with the help of 10 years climatic data from department of hydrology and meteorology.

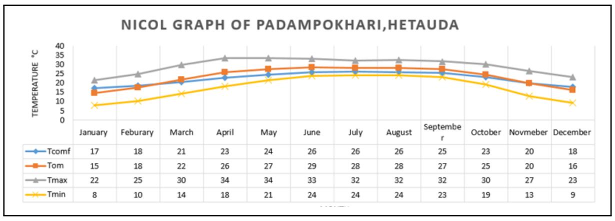


Figure 2: Nicol's graph of Hetauda

As shown in table, the highest temperature in which the people of Padam Pokhari,Hetauda feel comfortable is 31°C during summer.

Table 1: Nicol's comfort temperature for Hetauda

S.N.	Thermal sensation	Thermal scale	Nicol summer (Tc)	Nicol winter (Tc)	Comfort category	Remark
1	Hot	3	34	24	Very comfortable	
2	Warm	2	33	23	Uncomfortable	
3	Slightly warm	1	32	22	Comfortable	Comfortable zone
4	Neutral	0	31	21	Very comfortable	
5	Slightly cool	-1	30	20	Comfortable	
6	Cool	-2	29	19	Uncomfortable	
7	cold	-3	28	18	Very uncomfortable	

5.2 Selection of buildings

Nine different types of houses were selected for the measurement of air temperature in order to investigate the difference in indoor and outdoor temperature and compare which house was thermally comfortable to live in. First types of House 1: Three different Modern residential building: one and half storied modern frame structure building with brick wall and flat concrete roof.

Figure 3: Modern residential building

Table 2: U-value calculation of modern residential house M1, M2, M3

Building envelope (thickness)	Thermal Conductivity (W/(m·K))	R-value(thickness/conductivity)	U-value
Wall			
Outer brick wall 9" Cement plaster on both side of wall 12mm	1.15 0.72	0.2 0.016 0.016 Total R-Value=0.232	**4.3 W/m²K**
Roof			
Bitumen 20mm Rcc 100mm Plaster 12mm	0.25 0.2 0.72	0.8 0.5 0.016 Total R-value =0.596	**1.6 W/m²K**
Window single glazed	0.78	0.20	**4.8 W/m²K**

Second types of House 2: Three different Traditional residential building: two-storied with mud brick, wooden wall, and slope tile roof.

Figure 4: Traditional residential building

Table 3: U-value calculation of traditional residential house T1, T2, T3

Building envelope (thickness)	Thermal Conductivity (W/(m·K))	R-value(thickness/conductivity)	U-value
Wall			
Sun-dried brick 14" Mud Plaster First floor Wooden wall	0.9 0.65 0.12	0.3944 0.017 0.017 Total R-Value=0.4284 0.45	**2.3 W/m²K** **2.2 W/m²K**
Roof			
Tile	1.43	6.25	**0.16 Wm²K Tile**
Window wood	0.12	0.91	**1.09 W/m²K**

Third types of House 3: Three different Hybrid residential building: two storied with wooden wall and slope tile roof and half of modified with CGI roof.

Figure 5: Hybrid residential building

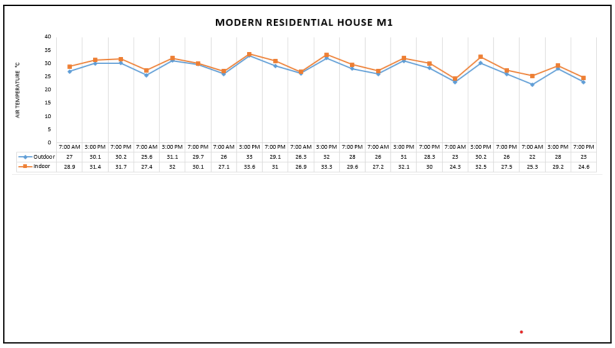
Table 4: U-value calculation of traditional residential house H1, H2, H3

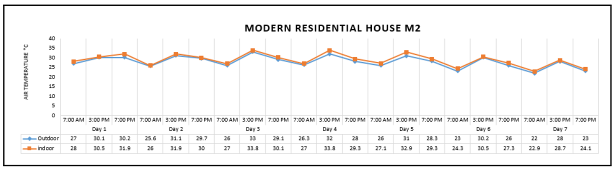
Building envelope (thickness)	Thermal Conductivity (W/(m·K))	R-value(thickness/conductivity)	U-value
Wall			
Wooden wall	0.12	0.45	**2.2 W/m²K**
Roof			
Tile CGI	1.43 36.86	6 0.17	**0.16 W/m²K Tile** **5.88W/m²KCGI**
Window wood	0.12	0.91	**1.09 W/m²K**
Wall			
Hollow concrete block9" Plaster Firs floor Wooden wall	1.95 0.72 0.12	0.1179 0.016 0.016 Total R-Value=0.1499 0.45	**6.67 W/m²K** **2.2 W/m²K**
Roof			
CGI Sheet 28 gauge	36.86	0.17	**5.88 W/m²K**
Window single glazed	0.78	0.20	**4.8 W/m²K**

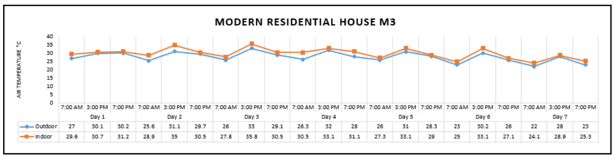
6. Findings and discussions

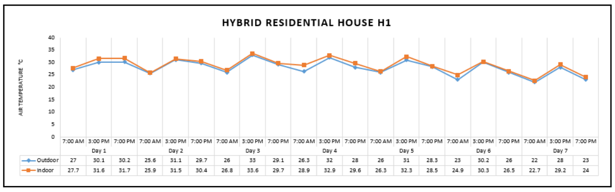
As seen in the table 5 difference in temperature in indoor and outdoor air temperature i.e., is seen maximum in 2.2 in summer condition. If we compare air temperature of traditional residential buildings with other investigated modern residential building, the difference of 2.6 was seen. This is the considerable difference which shows that the investigated modern building are 2.6 warmer during summer. If we compare air temperature of traditional residential buildings with other investigated hybrid residential building residential building, the difference of 2.5 was seen. This is the considerable difference which shows that the investigated hybrid building are 2.5 warmer during summer.

6.1 Comparison of indoor and outdoor air temperature in summer









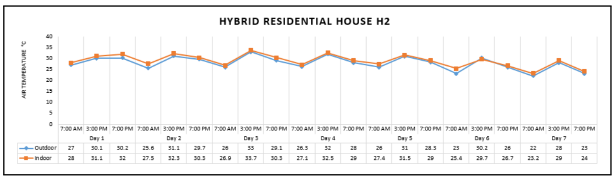


Table 5: mean maximum and mean minimum temperature of padampokhari ,Hetauda of summer

S.N	MODERN RESIDENTIAL BUILDING M1			MODERN RESIDENTIAL BUILDING M2			MODERN RESIDENTIAL BUILDING M2			HYBRID RESIDENTIAL BUILDING H1			HYBRID RESIDENTIAL BUILDING H2			HYBRID RESIDENTIAL BUILDING H3			TRADITIONAL RESIDENTIAL BUILDING T1			TRADITIONAL RESIDENTIAL BUILDING T2			TRADITIONAL RESIDENTIAL BUILDING T3		
Time	7:00 AM	3:00 PM	7:00 PM	7:00 AM	3:00 PM	7:00 PM	7:00 AM	3:00 PM	7:00 PM	7:00 AM	3:00 PM	7:00 PM	7:00 AM	3:00 PM	7:00 PM	7:00 AM	3:00 PM	7:00 PM	7:00 AM	3:00 PM	7:00 PM	7:00 AM	3:00 PM	7:00 PM	7:00 AM	3:00 PM	7:00 PM
Outdoor	27	30.1	30.2	27	30.1	30.2	27	30.1	30.2	27	30.1	30.2	27	30.1	30.2	27	30.1	30.2	27	30.1	30.2	27	30.1	30.2	27	30.1	30.2
Indoor	28.9	31.4	31.7	28	30.5	31.9	29.6	30.7	31.2	27.7	31.6	31.7	28	31.1	32	27.9	32.2	30.9	26	28.7	26	26.1	29.7	27.3	26.1	29.4	29
Mean max outdoor	29.1			29.1			29.1			29.1			29.1			29.1			29.1			29.1			29.1		
Mean max indoor	30.7			30.1			30.5			30.3			30.4			30.3			26.9			27.7			28.2		
ΔT	-1.6			-1.0			-1.4			-1.2			-1.3			-1.2			2.2			1.4			0.9		

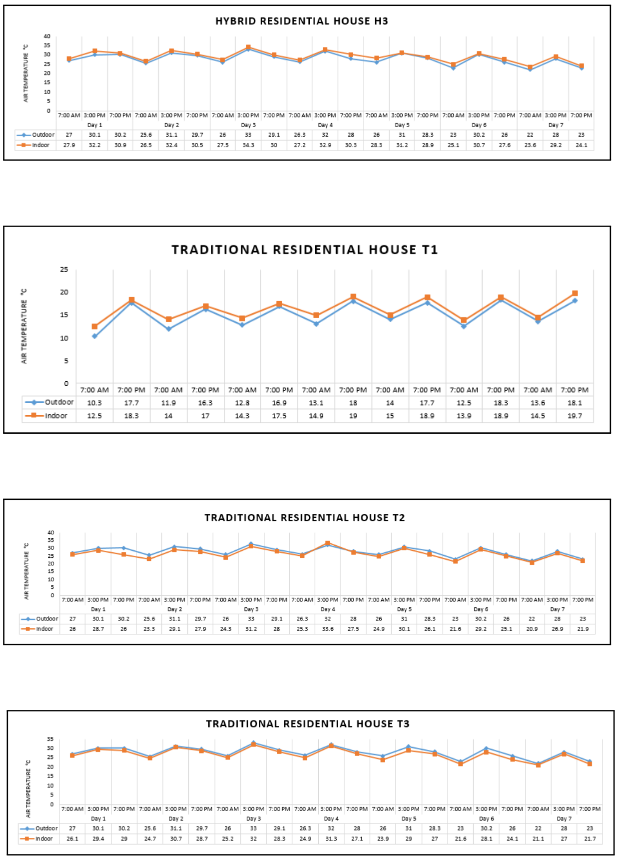


Figure 6: Graph of summer data of modern residential building M1, M2, M3, H1, H2, H3, T1, T2, & T3

6.2 Regression analysis

The prediction of indoor air temperature of nine different houses has been done by using regression analysis method. A total 540 data were plotted from each houses of 60 data set for analysis. Liner regression model is developed. The equation developed by regression analysis of nine different types of building is given below Modern residential RCC house: Ti=0.3861 To+17.356 Hybrid residential house: Ti=0.5874To+12.439 Traditional residential house: Ti=0.9368 To +3.475 Where, Ti= indoor temperature in °C To=Outdoor temperature in °C The maximum variation of more than 4°C cooler seen in traditional residential house in comaparsion with modern residential builing.

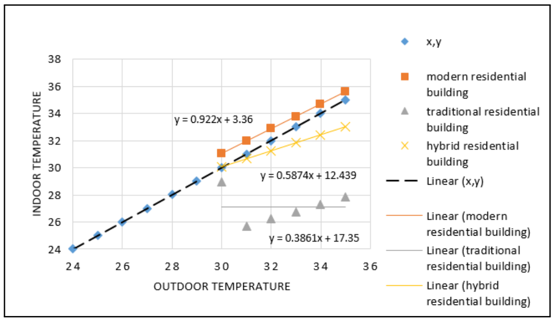


Figure 7: Regression analysis graph

Table 6: Regression table of summer season

House type	No.of sam	Equation	R2	To	Ti	To-Ti
modern residential builing M	24	Ti=0.922To+3.36	0.7491	20	21.8	-1.8
				21	22.722	-1.722
				22	23.644	-1.644
				23	24.566	-1.566
				24	25.488	-1.488
				25	26.41	-1.41
				26	27.332	-1.332
				27	28.254	-1.254
				28	29.176	-1.176
				29	30.098	-1.098
				30	31.02	-1.02
Traditional residential house T	24	Ti=0.3861To+17.3	0.5737	20	25.078	-5.078
				21	20.2276	0.7724
				22	20.7722	1.2278
				23	21.3168	1.6832
				24	21.8614	2.1386
				25	22.406	2.594
				26	22.9506	3.0494
				27	23.4952	3.5048
				28	24.0398	3.9602
				29	24.5844	4.4156
				30	25.129	4.871
Hybrid residential building H	24	Ti=0.5874To+12.4	0.7636	20	24.187	-4.187
				21	24.7744	-3.7744
				22	25.3618	-3.3618
				23	25.9492	-2.9492
				24	26.5366	-2.5366
				25	27.124	-2.124
				26	27.7114	-1.7114
				27	28.2988	-1.2988
				28	28.8862	-0.8862
				29	29.4736	-0.4736
				30	30.061	-0.061

7. Discussion

Modern residential U-Value seem to be highest in comparison with other types of a residential houses. Modern residential building walls and windows have the highest U-Value, it may be because of material use in the building construction. In Hybrid residential building U-value, roof with CGI sheet seem to be highest. Traditional residential building U-vale is very low in comparison with other residential buildings. Low U-value material help to perform good thermal performance of building (Walker, 2015).So traditional residential building perform a good thermal performance inside the building in comparison with other residential building.

Subjective response on over all thermal comfort in summer season of 3 types of residential building. While 38 percent of the residents of modern buildings voted for hot , 28 percent of the residents of hybrid buildings voted for the warm and 38 percent of the residents of traditional buildings voted for the /slightly warm neutral thermal inside the building. From all overall thermal comfort it is prove that people also feel the good thermal comfort inside the traditional residential building.

According to the respondents of the modern residential building, they feels extremely hot during the summer it may be because of the materials like wall material during construction. All of the occupants of the modern, hybrid residential houses depend on fan to survive in the uncomfortable conditions, to get thermal comfort ,it may be because of the materials like brick, and concrete hollow block. According to the respondents, of the traditional residential building. Respondent feels neutral during the summer it may be because of the materials like wood, sundried brick, tile. Also there is no uncomfortable situation inside the building.

8. Conclusion

The first objective of research assess the thermal performance of residential buildings of Hetauda is done by using room thermometer HTC-2.The key findings of research shows: investigated traditional residential building maintains the thermal performance of investigated traditional residential house was seen 1-1.2°C cooler in summer. Also from regression analysis The maximum variation of more than 4°C cooler seen in traditional residential house during time of summer.Where modern residential building seem to be warmer than of traditional residential building. Second objective the comparison use of modern materials, U-value maintenance different types of residential clearly shows that traditional use locally available material and have low U-Value of material which directly effects on the thermal performance of building. Also the perception of people also prove that the traditional residential building perform best thermal performance in comparison with hybrid and modern residential building. Traditional residential building material have less U-value in compare with modern materials, where in modern residential building found to be uncomfortable it may be because of material which has been used in residential building. In this way this project concludes by answering the entire objective. Finally recommendations at different levels has been provided for future study. In this way this project concludes by answering the entire objective.

9. Recommendation

In fields it is clear that traditional residential building seems to be with bad condition. Maintenance works, preservation things seems to be less in field in comparison with other types of residential buildings. So that the primary stakeholders, who are inhabitant of traditional residential house in Hetauda are recommended to carry regular or time to time maintenance, air tightness, green techno fitting of whole the traditional residential building and must know about importance of their vernacular architecture. It is recommended to the researchers that the improvement design strategies can be practically carried out in the field of modern residential building. Alternative design strategies from traditional construction material and technology can be adopt in modern residential building so that improve the thermal performance of modern residential building. People are adopting modern materials without knowing the importance of modern material residential building; it may be they have less knowledge about the importance of locally available materials and technology. So, Small awareness programs in the subtropical regions should be organized for the architects, local peoples who build residential houses by modern techniques using local resources.

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