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Thermal performance of Tharu house and its improvement techniques - A case of Dang-Deukhuri

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Abstract
The thermal performances of a building are governed by the factors like climatic condition, geographical location, material availability, lifestyle and socio-cultural activities. Usually traditional houses are seen performing well in this context than modern houses. The reason may be due to the use of indigenous and locally available materials in traditional houses. So,the research has objective to assess thermal performance of traditional Tharu house in Gobardiya village of Dang-Deukhuri district and to suggest improvement techniques.For that the research has been initiated by literature on Tharu house and settlement pattern of Dang-Deukhuri district, thermal performance, adaptive thermal comfort and improvement techniques. The indoor and outdoor temperature of one of the Tharu house of Gobardiya village for four consequent days in summer and winter has been collected in the field, which has been compared with the other three investigated houses of case area. The summer and winter comfort temperature of Dang has been calculated using Nicol adaptive thermal comfort model, which has been also compared with the assessed temperature of investigated Tharu house. The findings based on calculations and regression analysis shows that the investigated traditional Tharu house maintain 3.5℃ less temperature other investigated houses in summer and 2.13 ℃ more temperature in winter . Finally improvement techniques of traditional Tharu house has been suggested on the basis of literature review and recommendations at different levels has been provided for future study.

Keywords
Thermal performance, thermal comfort, climate, temperature, Tharu house, indegenious, traditional

1. Introduction

Nepal, the country rich in culture and tradition, is amalgamated with the various religion and castes of people who are diversified all over Nepal. The people following different religion and culture have their own type of history, culture, tradition and lifestyle. The culture, tradition, lifestyle and vernacular architecture of the people living in any area are shaped by their geographical region, topography and their religious beliefs. The daily lifestyle and activities of the people, climatic and geographical condition, their strong religious belief and socio-economic condition reflect culture, tradition, art and architecture of any place. [1] The traditional architecture could be one of the key issue for sustainable building design for different climates and cultures. They are well matched and adapted to the climates and cultures by using local building materials and techniques. [2] With regard to the vernacular architecture of Nepal in terms of geographical location, the difference is seen in terms of material availability and construction technology. The use of indigenous materials and construction technology makes the building thermally comfortable to live in. But in the present scenario the traditional houses are seen replicated by modern houses which has caused loss in the thermal comfort of the house.

The research has been carried out to assess the thermal performance of Tharu house of Terai region of Nepal taking Gobardiya village of Dang-Deukhuri district as a case area. The research has limitation that the thermal performance of only two seasons i.e. summer and winter is incorporated. Usually the traditional houses with the use of indigenous materials are cool in summer and warm in winter. So, the research has tried to quantitatively prove the statement through calculations and regression analysis. The

research findings is limited to investigated houses only, which does not intend to generalize all the houses of case area.

2. Objectives

Main objective:

- To assess thermal performance of Traditional Tharu house of Dang-Deukhuri in summer and winter condition incorporating its improvement techniques.

Specific objectives:

- To measure indoor and outdoor air temperature of traditional Tharu house and its effect in thermal comfort of house.
- To compare thermal performance of traditional Tharu house with other types of houses in case area
- To assess construction technology material properties of traditional Tharu house.

3. Methodology

The research has main objective to assess the thermal performance of traditional Tharu house of Dang-Deukhuri district in summer and winter and to suggest its improvement techniques. For this, the vital source of knowledge accumulation is through the experience both of the researcher and the local inhabitants, who are actually residing in the case area. The objective set lead towards quantitative research method rather than qualitative research method.

The research has been carried out in Gorbardiya village of Dang-Deukhuri district which is a typical Tharu village with maximum number of traditional Tharu houses.In order to fulfill the defined objectives, different research indicators has been selected, on the basis of which thermal performance has been assessed. On the basis of literature review 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 Dang from Department of Hydrology and Metrology,(GoN) and demogrpahic/housing data from report of VDC profile of Gobardiya village. The other methods like interview with key stakeholders, unstructured questionnaire survey, key informants meeting and mobile ethnography has been used.

The air temperature was taken 3 times a day for four consecutive days in both summer and winter for four investigated houses. A total of 240 data set in each summer and winter were taken using simple room thermometer. 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 assessed data were calibrated and the results and findings were drawn through calculation and regression analysis. The results and findings are limited to only investigated houses which do not intend to generalize all the traditional Tharu house of case area. The conclusion based on findings has been drawn and different improvement techniques based on literature has been suggested. Finally the recommendations at different levels for further works has been suggested.

3.1 Investigated buildings for Air temperature

Four 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. The investigated houses were based on the indicators like measurement of air temperature, orientation of houses, size of openings and materials used in the house. On the basis of these parameters the findings has been formulated. The four different types of house investigated were:

1. House 1:Traditional Tharu house: Single storied with mud wall and thatch roof
2. House 2: Traditional modified house (Thatch to CGI): Traditional Tharu house modified with CGI roof
3. House 3: Modern RCC house: Single storied modern frame structure building with brick wall and RCC roof
4. House 4: Mixed house: Single storied load bearing with CGI roof in half portion and laminated false ceiling in another half.

Figure 1: (a) House 1 (b) House 2 (c) House 3 (d) House 4

3.2 Air temperature measurement and data presentation

For the measurement of ambient temperature the thermometer (Simple room thermometer of Omsons 9001:2000) were placed at five different locations of each type of houses. Four locations were inside the house to measure the indoor temperature whereas one thermometer was placed outside the house to measure outdoor temperature. For the measurement of indoor air temperature the thermometer was placed in the internal wall at the height of 5 ft. (1.5m) from floor level. In the similar manner for the measurement of outdoor temperature the thermometer was placed at external wall. Care was given to avoid the direct sunlight into the thermometer. The indoor and outdoor air temperature of all the investigated houses was recorded at three different times of the day i.e. 7:00, 13:00 and 20:00 for four continuous days. 240 number of data set of air temperature was recorded which was then calibrated for the result and analysis.

3.3 Climatic data of Dang

- Climatic zone: Varies from Lower Tropical to Sub Tropical region (Varies: 300m-2000m)
- Geography/Land feature: Parallel inner Terai valley enclosing ranges of hills and mountain
- Ambient temperature Summer: Day 31.57°C, Night 23.86°C Winter Day 21.33°C,Night 8.35°C
- Relative Humidity Summer/Monsoon (Jun-Aug): 86.5% Winter (Dec-Feb): 82.2%
- Precipitation: 390.07 mm
- Winds: Variable (Usually SWS)

3.4 Comfort Temperature for Dang

Figure 2 shows Nicol graph for Dang which start finding the temperature in which people find comfortable to live, in which indoor air temperature varies with mean outdoor air temperature of outdoor temperature . It has been calculated from recent five years climatic data (2012-2016) of Dang assessed from Department of Hydrology and Metrology, Government of Nepal. The data of 10 years could not be taken due to limitation of time and resource. The comfort temperature varies according to the geographical location. The comfort temperature of Dang has been calculated using the Nicol formula shown in equation (i)

Tcomf = 0.54 Tom + 12.9.....(i)

The equation shown above helps for the calculation of Adaptive thermal comfort from monthly mean max (Tmax), monthly mean min (Tmin), monthly mean outdoor temperature (Tom) and monthly comfort temperature of 12 months.

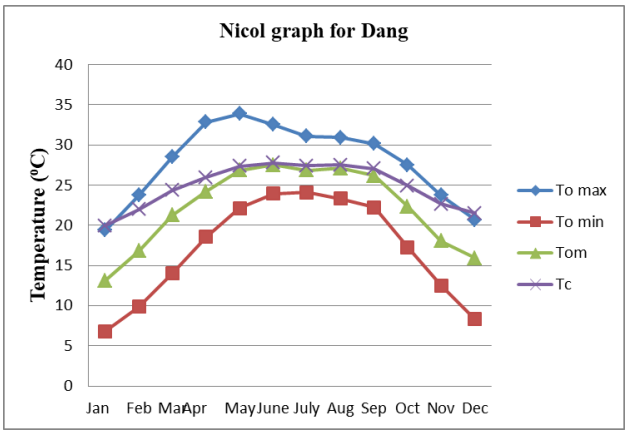

Figure 2: Nicol graph for Dang

As shown in the table 2, the lowest temperature in which the people of Dang feel comfortable is 17.5°C during winter, whereas the highest temperature in which the people of Dang feel comfortable is 27.6°C. 1°C rise and fall in the thermal sensation zone is acceptable since it lies in the comfort zone.

Table 1: Details of Investigated Houses

House no.	Owner	Typology	Orientation	Construction	Opening	Roof
House 1	K. Tharu	Traditional	North-South	Load bearing	6%	Slope
House 2	S. Tharu	Traditional CGI	North-South	Load bearing	8%	Slope
House 3	M.S Tharu	Modern	North-South	Frame structure	20%	Flat
House 4	D. Tharu	Modern-mixed	East-West	Load bearing	16%	Slope

Table 2: Nicol comfort temperature for Dang in summer and winter

Sno.	Th.sensation	Th.scale	Nicol summer	Nicol winter	Comfort category	Remarks
1	Hot	3	30.6°C	20.5°C	Very uncomfortable	
2	Warm	2	29.6°C	19.5°C	Uncomfortable	
3	Slightly warm	1	28.6°C	18.8°C	Comfortable	Comfort zone
4	Neutral	0	27.6°C	17.5°C	Very comfortable	Comfort zone
5	Slightly cool	-1	26.6°C	16.5°C	Comfortable	Comfort zone
6	Cool	-2	25.6°C	15.5°C	Uncomfortable	
7	Cold	-3	24.6°C	14.5°C	Very uncomfortable	

4. Data Presentation and Analysis

Table 3 and table 4 shows mean max and mean min temperature of four investigated buildings in 5 five different locations at three different times of the day in summer and winter respectively which was measured in the field. As seen in the table 3, the difference in air temperature was seen maximum in traditional Tharu house which is 2.08°C. If we compare it with other investigated houses with negative value, then the difference of nearly 3.5°C is seen in summer condition. In the similar manner, in table 4 for winter condition, temperature difference was again seen maximum in traditional Tharu house which is 2.13°C. The reason for the maximum air temperature variation in indoor and outdoor may be due to the use of the use of Thatch in roof and wall which have very low U-value.

4.1 Comparision of Air Temperature

Figures 3 – 10 show the graph of indoor and outdoor air temperature of four investigated houses in summer and winter. The result shows that the investigated traditional Tharu house performs well in both summer and winter condition. During morning and day time the ambient indoor air temperature of investigated traditional Tharu house varies considerably with outdoor air temperature in summer i.e. the difference of 3.5°C was seen when it was compared to other investigated houses. Likewise, the traditional Tharu house was seen warmer in winter season than other investigated houses by 2.13°C. The result can be seen in the graph as well table 3 and 4. It implies that the investigated traditional Tharu house is cooler in summer and warmer in winter than other investigated houses in the case area.

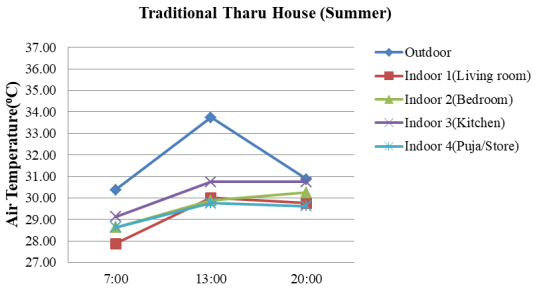

Figure 3: Graph of house 1 in summer

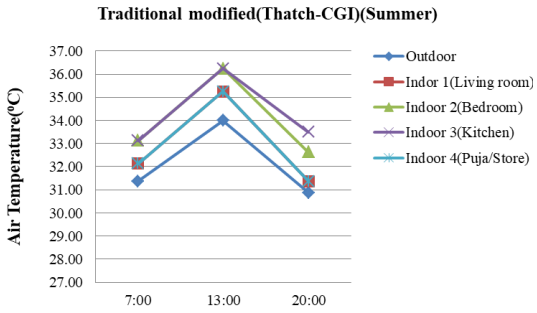

Figure 4: Graph of house 2 in summer

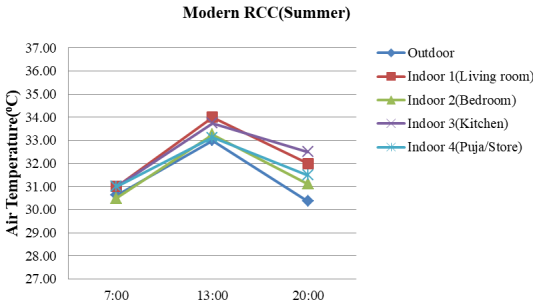

Figure 5: Graph of house 3 in summer

	Summer Mean Max Temperature (° C)											
S.no.		Traditional tharu house			Traditional modified(Thatch-CGI)			Modern RCC			Mixed house		
	Time	7:00	13:00	20:00	7:00	13:00	20:00	7:00	13:00	20:00	7:00	13:00	20:00
1	Outdoor	30.38	33.75	30.88	31.38	34	30.88	30.63	33.00	30.38	31.75	33.88	30.88
2	Indoor 1(Living room)	27.88	30.00	29.75	32.13	35.25	31.38	31.00	34.00	32.00	30.38	31.63	30.50
3	Indoor 2(Bedroom)	28.63	29.88	30.25	33.13	36.25	32.63	30.50	33.25	31.13	31.13	31.38	30.38
4	Indoor 3(Kitchen)	29.13	30.75	30.75	33.13	36.25	33.50	31.00	33.75	32.50	31.13	31.38	30.25
5	Indoor 4(Puja/Store)	28.63	29.75	29.63	32.13	35.25	31.38	31.00	33.13	31.50	32.13	34.38	31.38
Mean Max(Outdoor)		31.67			32.08			31.33			32.17		
Mean Max(Indoor all)		29.58			33.53			32.06			31.33		
ΔT		2.08			-1.45			-0.73			0.83		

Table 3: Mean max and mean min temperature of summer

	Winter Mean Max Temperature (° C)											
S.no.		Traditional tharu house			Traditional modified(Thatch-CGI)			Modern RCC			Mixed house		
	Time	7:00	13:00	20:00	7:00	13:00	20:00	7:00	13:00	20:00	7:00	13:00	20:00
1	Outdoor	5.75	17.38	11.50	5.75	17.38	11.50	5.75	17.38	11.50	5.75	17.38	11.50
2	Indoor 1(Living room)	9.13	15.00	13.75	6.75	17.88	12.75	7.25	16.50	13.75	11.00	16.38	15.50
3	Indoor 2(Bedroom)	10.88	14.50	16.13	7.50	19.50	13.00	9.13	15.25	13.75	10.88	14.88	14.63
4	Indoor 3(Kitchen)	11.00	16.13	15.88	7.50	20.13	13.88	9.25	15.88	15.63	8.63	18.63	14.75
5	Indoor 4(Puja/Store)	10.00	14.75	16.88	7.50	19.13	12.88	9.38	15.25	13.50	10.75	14.88	12.75
Mean Max(Outdoor)		11.54			11.54			11.54			11.54		
Mean Max(Indoor all)		13.67			13.20			12.88			13.64		
ΔT		-2.13			-1.66			-1.33			-2.09		

Table 4: Mean max and mean min temperature of winter

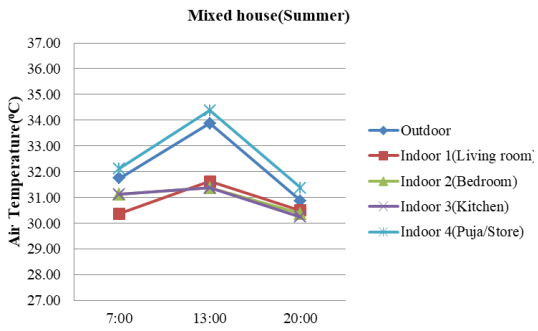

Figure 6: Graph of house 4 in summer

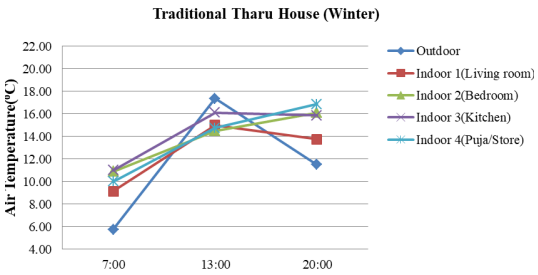

Figure 7: Graph of house 1 in winter

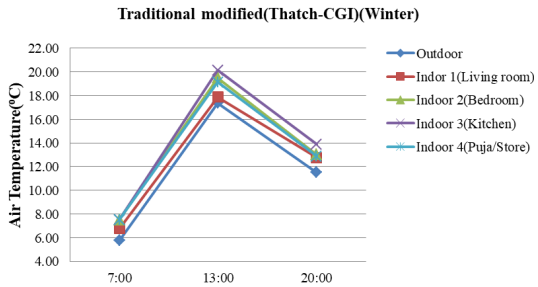

Figure 8: Graph of house 2 in winter

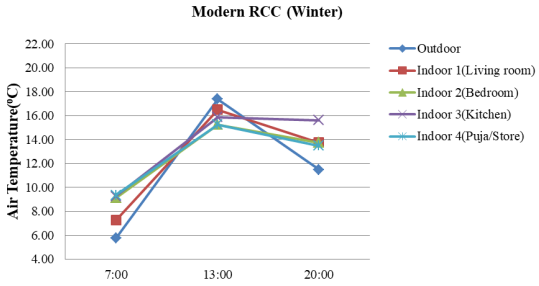

Figure 9: Graph of house 3 in winter

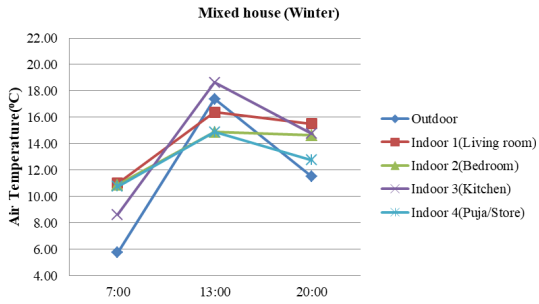

Figure 10: Graph of house 4 in winter

4.2 Regresion Analysis

The calculation of indoor air temperature of four different houses in summer and winter has been done by Regression analysis. A total of 240 data were plotted for the analysis in which each four houses consisted of 60 data sets, on the basis of which linear regression model was developed. Figure 11 and figure 12 shows the trend line of four houses in summer and winter condition. The regression equation for the individual houses in summer and winter can be seen

in table 5 and table 6 respectively.

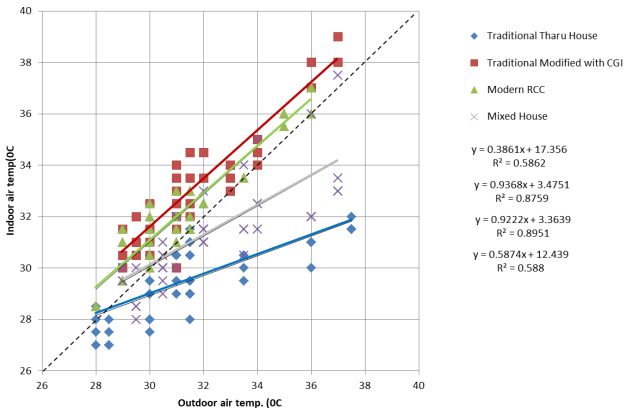

Figure 11: Regression analysis of indoor and outdoor air temperature of four different houses in summer

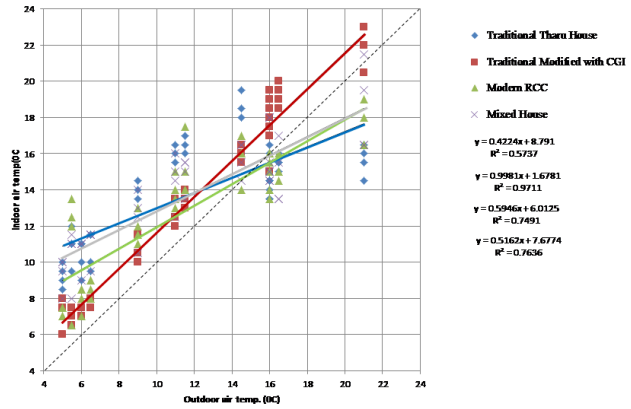

Figure 12: Regression analysis of indoor and outdoor air temperature of four different houses in winter

The result of summer condition shows that when outdoor air temperature for all four houses is taken 35°C, the maximum temperature variation of 4.13°C is seen in traditional Tharu house (Table 5). In the similar manner the result of winter condition also shows that when outdoor air temperature is taken 10°C for all four houses the maximum variation of 3.01°C again seen in traditional Tharu house(Table 6). Analyzing and comparing the trend lines of four different houses and from calculations, that the investigated traditional Tharu house was seen performing thermally better than other investigated houses.

House type	No. of samples	Equation	R2	To	Ti To	To-Ti
Traditional Tharu house	60	Ti = 0.3861To+17.356	0.5862	30°C	28.93°C	
				31°C	29.32°C	
				32°C	29.71°C	
				33°C	30.09°C	
				34°C	30.48°C	
				35°C	**30.87°C**	4.13°C
Traditional house modified with CGI	60	Ti = 0.9368To+3.4751	0.8759	30°C	31.57°C	
				31°C	32.51°C	
				32°C	33.45°C	
				33°C	34.39°C	
				34°C	35.32°C	
				35°C	**36.26°C**	-1.26°C
Modern RCC house	60	Ti = 0.9222To+3.3639	0.8951	30°C	31.03°C	
				31°C	31.95°C	
				32°C	32.88°C	
				33°C	33.80°C	
				34°C	34.72°C	
				35	**35.64°C**	-0.64°C
Mixed house	60	Ti=0.5874To+12.439	0.588	30°C	30.06°C	
				31°C	30.64°C	
				32°C	31.23°C	
				33°C	31.82°C	
				34°C	32.41°C	
				35°C	**32.99°C**	2.01°C

Table 5: Indoor air temperature of four houses from regression analysis in summer

House type	No. of samples	Equation	R2	To	Ti	To-Ti
Traditional Tharu house	60	Ti = 0.4224To+8.791	0.5737	5°C	10.90°C	
				6°C	11.32°C	
				7°C	11.74°C	
				8°C	12.17°C	
				9°C	12.59	
				10°C	**13.01°C**	-3.01°C
Traditional house modified with CGI	60	Ti = 0.9981To+1.6781	0.9711	5°C	6.66°C	
				6°C	7.66°C	
				7°C	8.66°C	
				8°C	9.66°C	
				9°C	10.66°C	
				10°C	**11.65°C**	-1.65°C
Modern RCC house	60	Ti = 0.5946To+6.0125	0.7491	5°C	8.98°C	
				6°C	9.58°C	
				7°C	10.17°C	
				8°C	10.76°C	
				9°C	11.36°C	
				10°C	**11.95°C**	-1.95°C
Mixed house	60	Ti=0.5162To+7.6774	0.7636	5°C	10.25°C	
				6°C	10.77°C	
				7°C	11.29°C	
				8°C	11.80°C	
				9°C	12.32°C	
				10°C	**12.83°C**	-2.83°C

Table 6: Indoor air temperature of four houses from regression analysis in winter

5. Data Discussion

The research shows that the thermal performance of the investigated traditional Tharu house is better in both summer and winter in comparison to other investigated houses of Dang-Deukhuri district. The temperature difference of 3.5°C was seen in traditional Tharu house in summer whereas the temperature difference of 2.13°C was seen in winter. This shows that about 35% of the energy inside the investigated traditional Tharu house can be economized in summer condition whereas 20% energy can be economized in winter condition. The investigated traditional Tharu house was in normal condition; had the house been in well maintained condition, better result than the resent could have been achieved.

The research that have been carried out in summer and winter shows that the investigated traditional Tharu house has better thermal performance. It may be due to the use of locally available materials and construction

technology. The materials used in the construction of Tharu houses like thatch and red mud has very low U-values due to which the heat loss is very low. It is well known fact that the material having high U-value has high heat loss whereas the material having low heat value has low heat loss. The U-value of thatch roof is about 0.2 W/m2 k which is very low in comparison to CGI and RCC roof. Furthermore, the regression analysis that has been conducted for the calculation of indoor air temperature in both summer and winter shows the better result in traditional Tharu house in comparison to other investigated houses in the case area.

6. Improvement techniques

The influence of modern materials and construction technology, poor construction technology and problem of maintenance in traditional houses are some of those factors which is causing in declining vernacular architecture.Some of the techniques that have been seen practicing in Historic England to insulate the Thatched roof are shortly described below:

- Torching: Mortar-coating applied to the underside of the thatch itself, either in an earth daub or a lime plaster. The torching reduced draughts and gave an internal finish.
- Boarded Ceilings: Close-boarding above the rafters can be left exposed to the underside, examples can be found in many 19th century buildings.
- Lath and plaster ceilings and partitions: Many roofs were under-drawn with earth or lime plaster fixed to laths or wattles. In many cases the plaster is contemporary with the construction of the building and is an important part of its history. [3]

6.1 Insulating Thatch roof-Adding insulation from above

The addition of insulation from above should only ever be considered if it is essential for a thatched roof to be stripped back to the rafters. . If the building is listed, consent will usually be required to strip back thatch to the rafters. [3]

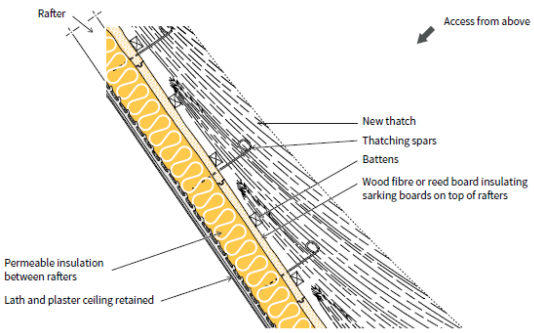

Figure 13: Warm roof – sloping ceiling (White, 2012)

6.2 Insulating Thatch roof-Adding insulation below the rafters

An insulated ceiling layer can be added to the underside of rafters where sloping ceilings are not of any historic value or are badly damaged.The biggest advantage of a new ceiling is that it will allow air infiltration to be blocked without removing the thatch. [3]

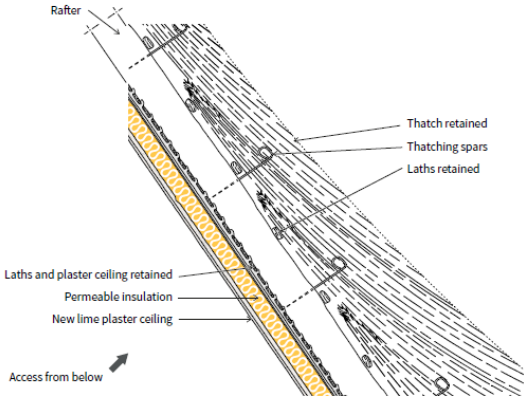

Figure 14: Warm roof – sloping ceiling (White, 2012)

6.3 Straw bale house construction

Straw bales are a highly insulative, low-embodied-energy, natural building material made from an agricultural waste product. For many, they are locally available and affordable. Straw is easy to work with for people new to construction as they are flexible and can be very forgiving.. Advantages of straw-bale construction over conventional building systems include the renewable nature of straw, cost, easy availability, naturally fire-retardant and high insulation value. [4]

The main purpose of doing literature on straw bale house is that, the Thatch roof which is being used in Traditional Tharu houses could also be developed as

option as straw bale, which would help in improving the shortcomings of Thatch roof.

Figure 15: Straw bale construction(Muskrats, 2018)

7. Findings and Conclusion

The research was set toward the main objective to assess thermal performance of traditional Tharu house and to suggest improvement techniques, which was supported by other specific objectives. The defined objective has been fulfilled since the field research has quantitatively proved that the investigated traditional Tharu house is cooler in summer and warmer in winter and show better thermal performance than other investigated houses. The objective to suggest improvement techniques has been also been fulfilled through literature study. The key findings of research are:

- Investigated traditional Tharu house maintains comfort temperature of Dang which is 27.6°C in summer and 17.5°C in winter.
- The thermal performance of investigated traditional Tharu house was seen better since it was found to be 3.5°C cooler in summer and 2.13°C warmer in winter.
- On the basis of field survey, traditional tharu house economies 35 percent of the energy in summer and 20 percent in winter; viz:1°C temperature reduction= 10 percent energy economized. [5]
- Traditional Tharu house thermally comfortable to live in both summer and winter which has been verified through calculation and regression analysis.

8. Recommendations and Further works

- It is recommended to researchers to incorporate air temperature of all four season to validate research objective more accurately.
- The further work can be carried out by incorporating other climatic factors like rainfall/humidity and more accurate instruments like data logger can be used.
- It is recommended to the researchers that the improvement techniques can be practically carried out in the field.
- The primary stakeholders, who are inhabitant of traditional Tharu house are recommended to carry regular maintenance of thatch roof and know about importance of their vernacular architecture.
- It is recommended to designers to use the indigenous materials in more effective way like making compressed block of thatch and using it as a building block in wall and roof.

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