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Study of Thermal Comfort in Terai Region of Nepal – A case of School Building in Kapilvastu District

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Abstract
Global average surface temperature has increased by more than 1.6 degrees Fahrenheit (0.9 degrees Celsius). Similarly the temperature of Nepal is warming at the rate faster rate than that of the global average temperature. Thermally discomfort creates the negative impact in the academic performance, so there should be serious attention to improve the indoor thermal environment of classroom. Adaptation to climate change is a functional requirement and best way of insulating is to have well-defined thermal boundary in building. All of the existing schools in Nepal have been constructed without any concern for the comfort of the occupants and the adaptation of the buildings to the local climate. This research focuses on evaluating and comparing effect of envelopes in uninsulated prototypical school with thermally insulated in Kapilvastu district. This study will help to report the thermal environmental conditions of classrooms in the schools of Kapilvastu. Primary data would be collected through school survey and case studies while secondary data would be collected through various literatures. The comfort temperature of Kapilvastu has been calculated using the Nicol formla, the lowest temperature in which the people of Kapilvastu feel comfortable is 20.3℃, whereas the highest temperature in which the people of Kapilvastu feel comfortable is 28.6°. For KVM School reduction in monthly load is 8% for scenario 2, 22% for scenario 3 and 20.6% for scenario 4.For Udayapur School reduction in monthly load is 41.49% for scenario 2, 31.5% for scenario 3 and 46% for scenario 4. The findings based on calculations Material with lesser U-value can save 10-40% monthly cooling or heating load in summer than uninsulated buildings of Kapilvastu.

Keywords
Adaptive thermal comfort, Comfort Temperature, Adaptive thermal comfort

1. Introduction

Advancement in addressing climate factors in building help to reduce the energy consumption of the building and help to improve the thermal comfort of the occupants according to [1], the correlation of the local climate with the shape and the thermal performance of the building is the major considerations of the passive design approaches to reduce the energy use of the building and increase the thermal comfort of the occupants. However, improving the indoor environment and reducing building's energy consumption is one of the conflicting criteria [2]. Buildings sector only consume up to 40 % of the total energy consumed in developed countries, whereas it is anticipated that developing nations will likely consume more energy than advanced nations by 2020 [2]. The students spend about their 30% of daily lives in school [3].Thermal comfort is one of the most important indicators for indoor quality and it is defined through [Ansi/Ashrae.] as the state of mind that expresses satisfaction with the thermal environment in which it is located. Thermal comfort is affected by different parameters like heat, conduction, radiation, convection and heat losses by evaporation. The building design code which has been issued by the Government of Nepal which does not address the issue of thermal comfort ,so it is major cause for the performance of poor indoor thermal comfort [4]. Schools are one of the building types necessarily of great interest when we consider the potential links between building performance, general sustainability, and the benefits of productive ,a healthy,and comfortable environment [5]. Thermal conditions in class- rooms have to be considered carefully mainly because of the high occupant density in classrooms and because thermal dissatisfaction cause negative effect on learning and performance of the students [6]. [7] Points out that the envelope of a building is not only a separator from the external environment but it acts as a prevention for climatic elements and protect the building directly. A building interacts with the environment through its external facades such as roof, walls, openings, floor and projections referred as building envelope. The envelope acts as a thermal envelope, which if thoughtlessly constructed, would result in energy leaks through every component. Therefore, each components of buildings needs to be properly chosen to ensure an energy efficient building.[8]. Most of the developed countries are conducting the thermal comfort survey in school buildings and other types of buildings. But in case of Nepal, study on thermal comfort in school building has not been studied. Few number of research has been conducted in a residential buildings[9, 10].

1.1 Need and Importance of research

In case of Nepal Most of the existing schools in have been constructed without any concern of the occupants thermal comfort and the adjustment of the buildings to the local climate, so there is necessary to provide thermal comfort for the occupants and maintain quality of construction of the school building. Exploring the thermal environmental comfort in school building is very important because children are very sensitive to temperature variations, in context of physical comfort there should be serious consideration it is a critical issue. Study of thermal comfort in Terai region Nepal is very necessary in case of school building of Terai region. However light building material with less U value are recommended for the hot and humid monsoon season. Light weight and well insulated roofs are recommendable for this climate [11]. According to kathmandupost 135,427 students are studying in 431 community schools and other educational institutions in Kapilvastu. Many researches and experiences on the residential, office buildings and other commercial building has been done but almost nothing has been done in the passive school buildings [9].

1.2 Research objective

Main Objectives

- Main objectives of the study is to increase thermal condition of the school building by upgrading thermal comfort in the indoor area.

Specific objectives of the research

- To report the thermal environmental conditions of classrooms in the schools of Kapilvastu.
- To find out comfort temperature of the study area.
- To find out comfort temperature of the study area.

2. Materials and Methods

2.1 Study Area

The research has been carried out in the schools of Boadgaun area of Kapilvastu district. Qualitative and exploratory research is carried out to gain in depth knowledge regarding the study of thermal environmental state of in the classroom of school building. The data collection was carried out in the field.The primary data collection included the measurement of air temperature, school detail measurement in the field whereas secondary data collection included climatic data of Kapilvastu from Department of Hydrology and Metrology.

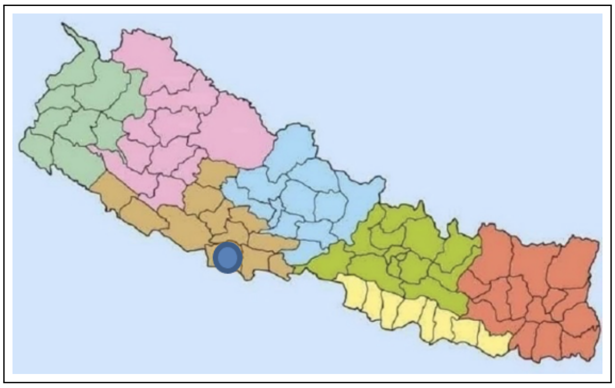

Figure 1: Location of Kapilvastu on the map of Nepal (Department of hydrology and meteorology

Climate of Kapilvastu: Kapilvastu district is located at a height of 93 to 1,491 meters (305 to 4,892 ft) above sea level, which lies in subtropical and warm temperate climatic region. In the summer season the temperature reaches above 27 °C and similarly in the winter temperature remains below 15 °C .

Geographically, the Kapilvastu district has been divided into the low land plains of Terai and the low Chure hills. Its climate is extremely hot upto 41°C and humid in summer and very cold and fuggy in winter.

Table 1: Climatic zones in Nepal (Source: Borgkvist, I. 2017

Climatic zone	Altitude[m]	Mean Temp°C Winter	Mean Temp°C Summer
Sub-Tropical	0-1200	15	>30
Warm Temperate	1200-2100	10	24-30
Cold Temperate	2100-3300	<5	20
Alpine	3300-5000	<0	10-15
Tundra	Above 5000	<0	<0

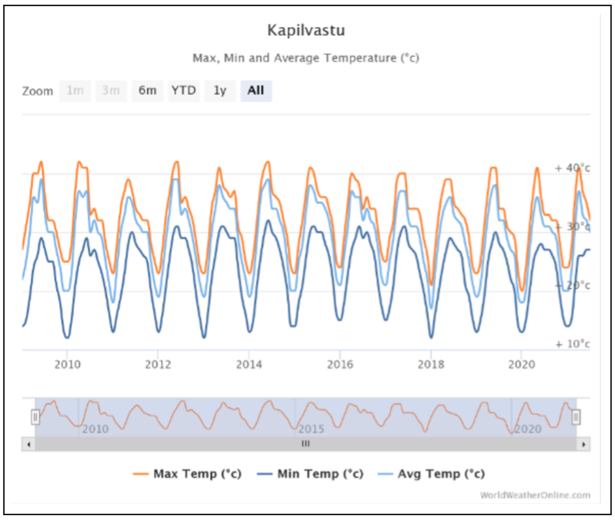

Figure 2: Max,Min and Average Temperature

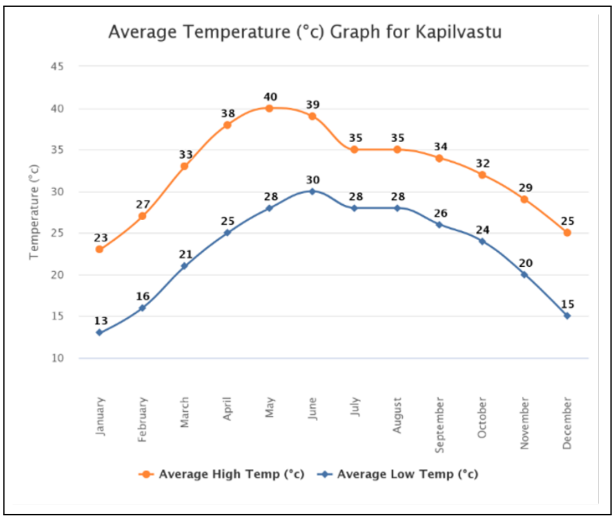

Figure 3

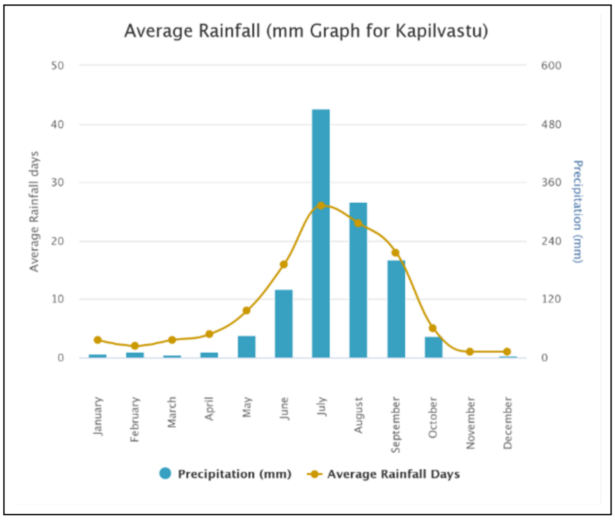

Figure 4: 2Graphs showing max., min., average temperature (C); average rainfall (mm) (Source: Weather online.com

2.2 Building Description

Three different types of school were selected for the measurement of air temperature in order to investigate the difference in indoor temperature and compare the temperature variation of investigated building. The schools are Kapilvastu Vidhya mandir (KVM), Udayapur School and Shainik Shining English School . The investigated School were based on the indicators like measurement of air temperature, size of openings and materials used in the house. On the basis of these parameters the findings has been formulated.

Table 2: Detail of school 1

Element	Description	Details
External Wall	Total area: -3088 sq.ft Wall thickness: 9" Insulation: no	9"brick wall + 15 mm cement plaster
Roof	Total area:4004 sq.ft Insulation: no	125 mm reinforced concrete slab
Floor	Ground floor area: 3088 sq.ft Firstfloorarea:3088 sq.ft	Heavy concrete slab of 125mm
Windows	Total window area = 648 sq.ft No of Classroom windows=24 no	Single-glazed 6 mm windows + wooden frame
Room Height	10'	

Table 3: Detail of school 2

Element	Description	Details
External Wall	Total area:3055 sq.ft Wall Thickness: 4" Insulation: no	4"brick wall + 15 mm cement plaster
Roof	Total area3187 sq.ft tiles Insulation: no	CGI roof 1 mm Roof thickness
Floor	Ground floor area: 3055 sq.ft	M15 Concerete for DPC of 100mm thick
Windows	Total window area = 240sq.ft No of Classroom windows=12 no	Wooden windows + wooden frame
Room Height	10'	

Table 4: Detail of school 3

Element	Description	Details
External Wall	Total area: -3132 sq.ft Wall thickness: 9" Insulation: no	9"brick wall + 15 mm cement plaster
Roof	Total area3150 sq.ft tiles Insulation: no	125 mm reinforced concrete slab
Floor	Ground floor area: 3132 sq.ft	Concerete slab of 125mm
Windows	Total window area = 360sq.ft No of Classroom windows=18 no	Wooden windows + wooden frame
Room Height	10'	

School 1: Kapilvastu Vidhya Mandir School: Two storied RCC modern frame structure building with brick wall and RCC roof.

School 2: Udayapur School: One story building with CGI roof.

School 3: Shainik Shining English school: Single storied RCC modern frame structure building with brick wall and RCC roof.

2.3 Methods

The research has been carried out in the schools of Boadgaun area of Kapilvastu district. Qualitative and exploratory research is carried out to gain in depth knowledge regarding the study of thermal environmental conditions of classrooms in the school building of kapilvastu. The data collection was carried out in the field. In order to fulfill the defined objectives, different research indicators has been selected, on the basis of which thermal performance has been carried out. 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 door windows, size of wall 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, school detail measurement in the field whereas secondary data collection included climatic data of Kapilvastu from Department of Hydrology and Metrology. The thermal environmental conditions of classrooms in the schools of kapilvastu was measured and analyzed. By this we achieve our First objective of the study. The comfort temperature of Kapilvastu has been calculated using the Nicol adaptive thermal comfort model. By this we achieve our second objective of the study. To achieve our third objectives, the thermal behavior of different building materials are analyzed in Ecotect software. For the simulation two different structure building, Kapilvastu vidjya Mandir(RCC frame building) school and Udayapur School (CGI roof building) were selected. The effect of envelopes in uninsulated prototypical schools were compared with thermally insulated by Ecotect simulation.

Air temperature measurement and data presentation

For the measurement of ambient temperature the thermometer (Simple room thermometer of HTC-1) were placed at 3 different school. For the measurement of indoor air temperature the thermometer was placed on the desk of the classroom, desk was placed at the center of classroom. During the summer season from 5 to 15 july, the indoor air temperature of all the investigated building was recorded at three different times of the day i.e. nearly 12:00, 1:00 and 2:00 for ten continuous days.

3. Data Analysis

3.1 Air temperature measurement and data analysis

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% ([12] . The average indoor temperature is

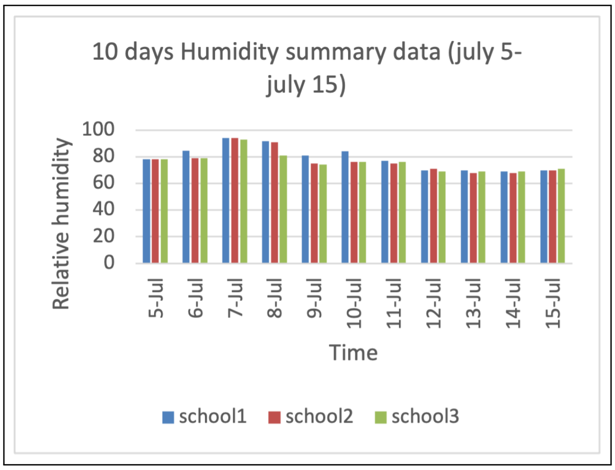

Figure 5: 10 days Humidity summary data

monitored in different schools, during the peak hour from (12pm-2pm).The maximum average temperature recorded in the Kapilvastu Vidhya Mandir secondary school (KVM) was 32°C, in the Udayapur school was 32.7 °C, and in Shainik shining English school was 32.4°C. Here we can see the maximum temperature recorded was 32.7°C in Udayapur school,this indicates there was poor thermal performance of the envelope in the Udayapur school. The reason for the maximum air temperature variation in Udayapur school may be due to the use of the use of CGI in roof, which have high U-value.

The average humidity is also monitored in different schools, during the peak hour from (12pm-2pm).The average humidity recorded from july 5 to july 15 in the Kapilvastu vidhya mandir secondary school (KVM) was 79%, in the Udayapur school was 77.6%, and in Shainik shining English school was 78%.

3.2 Comfort Temperature for Kapilvastu

According to Nicol, the 'adaptive comfort temperature' is the temperature which people finds comfortable in a given situation.

Figure 6 shows Nicol graph for Kapilvastu 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 climatic data (1980-2010) of Kapilvastu assessed from Department of Hydrology and Metrology, Government of Nepal. The comfort temperature varies according to the geographical location. The

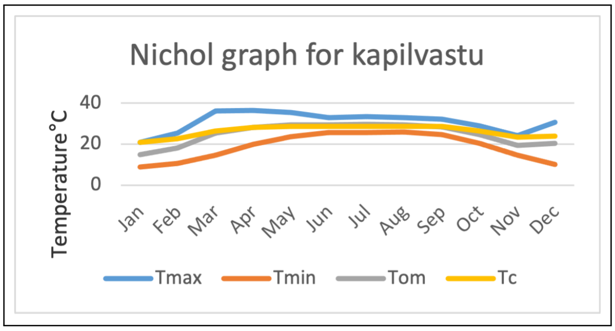

Figure 6: 10 days Temperature summary data

comfort temperature of Kapilvastu has been calculated using the Nicol formula shown in equation.

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 As shown in the table fig 5, the lowest temperature in which the people of Kapilvastu feel comfortable is 20.3°C during, whereas the highest temperature in which the people of Kapilvastu feel comfortable is 28.6°.

3.3 Ecotect Simulation

The energy modelling was performed through a simulation tool to compare the effect of envelopes in uninsulated prototypical schools with thermally insulated. To attain this objective, various necessary features of a school building at Kapilvastu was studied.

For the simulation two different structure building such as Kapilvastu vidjya Mandir school (RCC frame building) and Udayapur School (CGI roof building) were selected. The collected documents and drawings were drafted according to site conditions. The software adopted for simulation of the building is Autodesk Ecotect 2011. After combining the weather file in Ecotect, thermal analysis was the major concern to study the comfort level of the building. Parameters such as the monthly load of the building, heat loss and heat gain were calculated for thermal analysis. Also, the building is simulated creating different building envelopes as scenario cases. The focus of the simulation was an investigation of building envelope elements. Different four scenario were created. The results are mainly represented through monthly loads and heat gain and heat loss for a better understanding of the performance of building materials and its subsequent energy requirements. The U-value of Brick wall (1.8 W/m2K) which is higher than other 8” AAC block (0.71 W/m2K) , 3”Eco panel (0.315 W/m2K) and double brick cavity wall (1.780 W/m2K). [13].

Table 5: 5U-value of diffrent materials

Materials for construction	Materials detail	U-value (W/m2 K)
AAC block	Plaster lining (3 cm) AAC block (20 cm) Sand and cement mortar (3 cm) Exterior stone finishing (2 cm)	0.71
A2 AAC block	Plaster lining (3 cm) AAC block (10 cm) Cavity filled with expanded polystyrene (EPS) (5 cm) AAC block (10 cm) Sand and cement mortar (3 cm) Exterior stone finishing (2 cm)	0.37
Double brick cavity wall	110mm double brick plus 50mm cavity, with 10mm plaster inside.	1.780
Eco panel	Eco panel 30mm Eco panel 40mm Eco panel 50mm Eco panel 60mm Eco panel 75mm Eco panel 00mm	0.727 0.563 0.460 0.388 0.315 0.240

Kapilvastu Vidhya Mandir School Kapilvastu Vidhya mandir is two storey building which has altogether 14 room. The building is facing south direction. The Kapilvastu Vidhya Mandir school is constructed using different construction material stone,brick, mortar plaster, wooden timber etc. The structure of the building is Reinforced Concrete Construction (RCC). The existing buildings is not well insulated and the students of the this area have to accept the variety of indoor thermal conditions.

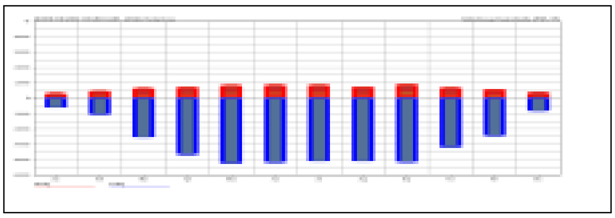

Figure 7: Monthly Heating cooling load

Scenario 1 is base line scenario was modelled as an existing scenario. All specification were as per site data collection and conditions. This scenario was modelled with the best possible way to represent the actual finding in the site. Other three different scenarios are created using different material. The material used are AAC block, EPS sandwich panel and double brick cavity wall and Green roofing. Ecotect use known thermal values of the various layers of building material to calculate overall thermal resistance of the system.

Table 6: Monthly heating/cooling loads base scenario

Month	Heating (Wh)	cooling (Wh)	Total (Wh)
Jan	7467	215	7682
Feb	28577	82282	110858
Mar	41737	391029	432767
Apr	52041	577324	629365
May	65248	639483	704731
Jun	66486	632998	699483
Jul	64367	626024	690391
Aug	55331	623975	679306
Sep	66751	647317	714068
Oct	49016	528816	577832
Nov	36505	347214	383719
Dec	16713	4797	21510
TOTAL	550238	5101474	5651712

Scenario 1: Heating load required is 550238Wh, Cooling load required is 5101474Wh and total load required throughout the building is 5651712Wh. Max Heatingload required is 637W at 05:00 on 3rd FebruaryMax Cooling load required is 2415W at 13:00 on 8th October.

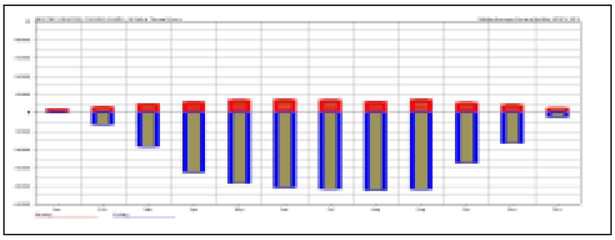

Figure 8: Monthly Heating cooling load

Scenario 2: Heating load required is 955809Wh, Cooling load required is 4204190Wh and total load required throughout the building is 5159999Wh. Max Cooling load required is 1836 W at 13:00 on 21st May.

Scenario 3: Heating load required 686249Wh, Cooling load required is 3721450Wh and total load required throughout the building is 4407699Wh. Max

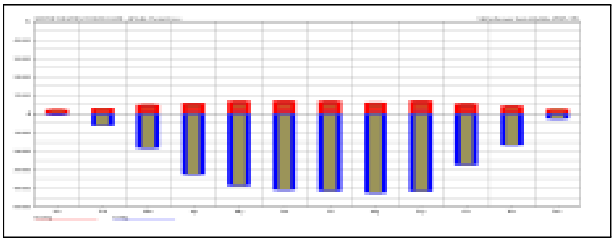

Figure 9: Monthly Heating cooling load

Cooling load required is 1793 W at 16:00 on 31st May.

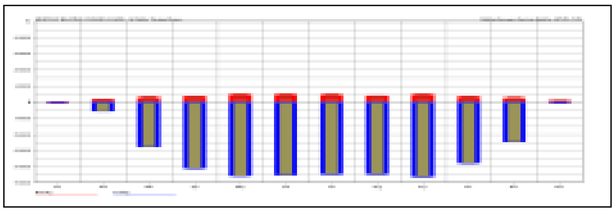

Figure 10

Scenario 4: Heating load required 764310Wh, Cooling load required is 3722449Wh and total load required throughout the building is 4486759Wh. Max Cooling load required is 1679 W at 16:00 on 30th June.

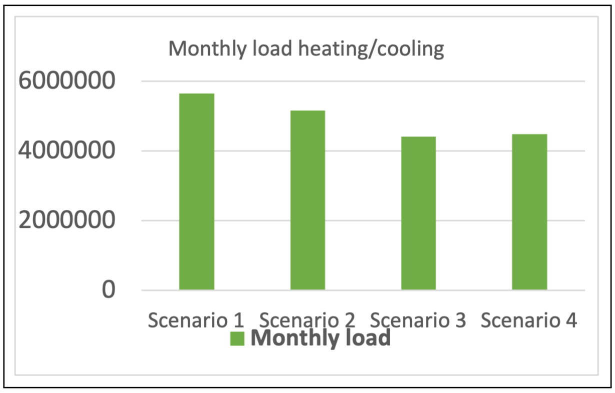

Figure 11: Comparison of monthly total heating/cooling load of different scenario.

Fig above shows the Comparison of monthly total heating/cooling load of different scenario in KVM school. Total monthly load required for scenario 1 is 5651712Wh, for scenario 2 is 5159999Wh, Scenario 3 is 4407699Wh and scenario 4 is 4486759Wh.

Table 7: Diffrent scenario for different material

Criteria	Scenario 1(base)	Scenario 2	Scenario 3	Scenario 4
Wall	Wall 9 inch brick wall +inner plaster 15mm	Eco panel 80mm	AAC block 8 inch	Double brick cavity wall
Floor	Floor Rcc125 mm +40mm screed	Floor concrete Rcc125 mm +40mm screed	Floor Rcc125 mm +40mm screed	Floor Rcc125 mm +40mm screed
Roof	Concrete slab 125mm	Green roofing	Green roofing	Green roofing
Openings	Single-glazed 6 mm windows +wooden door	Wooden windows +Hollow core ply wood door	Wooden windows +Hollow core ply wood door	Wooden windows +Hollow +wooden door

Udayapur School The school building has two blocks. This one storey building has altogether 8 rooms. The buildings is constructed using brick and mortar plaster. The roof structure of the building CGI sheet. Buildings is not well insulated and the students have to accept the variety of indoor thermal conditions.

Scenario 1 is base line scenario was modelled as an existing scenario. All specification were as per site data collection and conditions. Other three different scenarios are created using different material. The material used are AAC block, EPS sandwich panel and double brick cavity wall and UPVC roofing. Ecotect use known thermal values of the various layers of building material to calculate overall thermal resistance of the system.

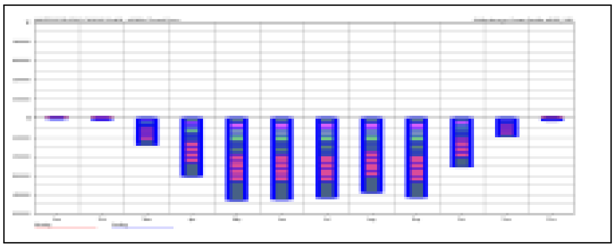

Figure 12

Scenario 1: Heating load required is 2210791Wh, Cooling load required is 66741648Wh and total load required throughout the building is 68952440Wh.

Table 8: Monthly heating/cooling loads base scenario

Month	Heating (Wh)	cooling (Wh)	Total (Wh)
Jan	881440	18683	900123
Feb	327998	652685	980683
Mar	4991	3835512	3840503
Apr	0	7456884	7456884
May	0	9969482	9969482
Jun	0	9659174	9659174
Jul	0	9111987	9111987
Aug	19831	8324052	8343883
Sep	0	8761830	8761830
Oct	0	5888282	5888282
Nov	11098	2862003	2873100
Dec	965432	201077	1166510
TOTAL	2210791	66741648	68952440

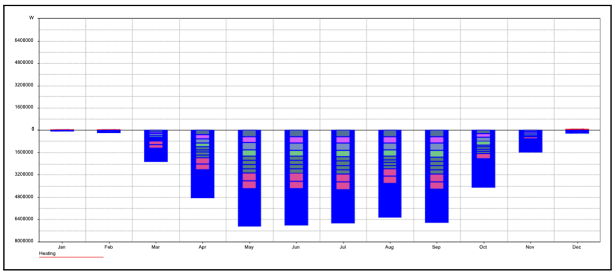

Figure 13: Monthly heating/cooling load

Scenario 2: Heating load required is 57187Wh, Cooling load required is 40535120Wh and total load required throughout the building is 40592308Wh.

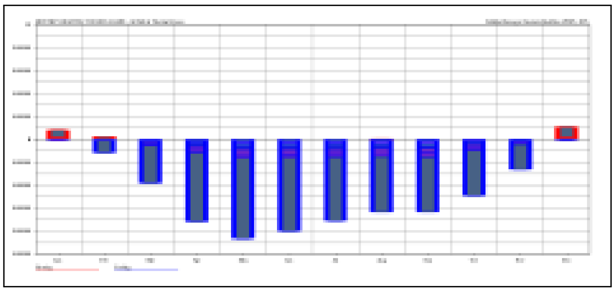

Figure 14: Monthly heating/cooling load

Scenario 3: Heating load required is 47219Wh, Cooling load required is 47190720Wh and total load required throughout the building is 47237940Wh.

Scenario 4: Heating load required is 161704Wh, Cooling load required is 37046396Wh and total load required throughout the building is 37208100Wh.

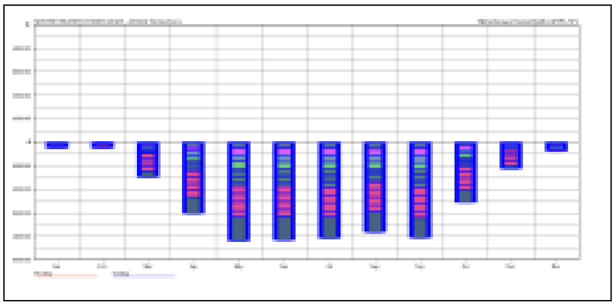

Figure 15: Monthly heating/cooling load

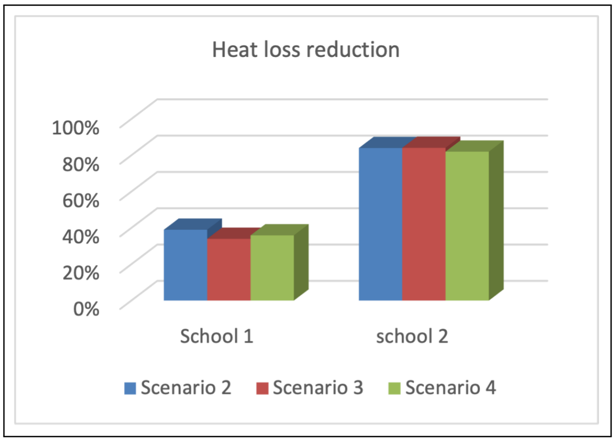

Figure 16: Comparison of monthly total heating/cooling load of different scenario

Fig above shows the Comparison of monthly total heating/cooling load of different scenario in Udayapur School. Total monthly load required for scenario 1 is 68952440Wh, for scenario 2 is is 40592308Wh, Scenario 3 is 47237940Wh and scenario 4 is 37208100Wh.

Fig above shows the Comparison of monthly total heating/cooling reduction load of different two school. For KVM School reduction in monthly load is 8% for scenario 2, 22% for scenario 3 and 20.6% for scenario 4. . For Udayapur School reduction in monthly load is 41.49% for scenario 2, 31.5% for scenario 3 and 46% for scenario 4.Reduction in monthly total heating/cooling load is high in Udayapur School.

Fig above shows the Comparison of heat loss reduction load of different two school. For KVM School reduction in heat loss is 39% for scenario 2, 34% for scenario 3 and 35.9% for scenario 4. . For Udayapur School reduction in heat loss is 75.4% for scenario 2, 75.6% for scenario 3 and 74% for scenario 4.

Fig above shows the Comparison of heat gain reduction load of different two school. For KVM School reduction in heat gain is 13% for scenario 2, 12% for scenario 3 and 6% for scenario 4. For Udayapur School reduction in heat gain is 52.2% for

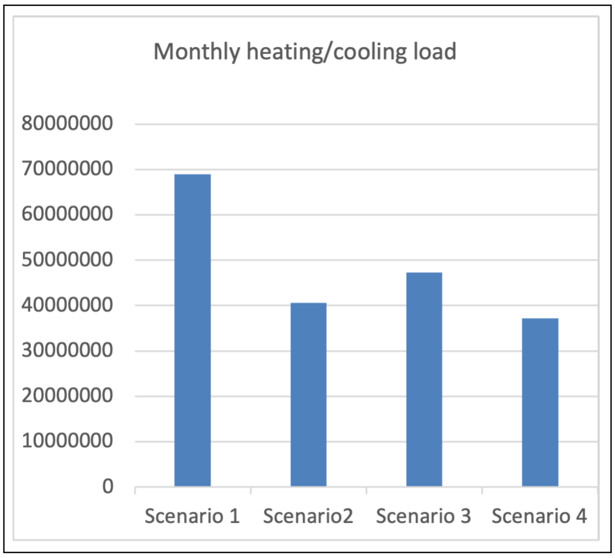

Figure 17: Monthly load reduction

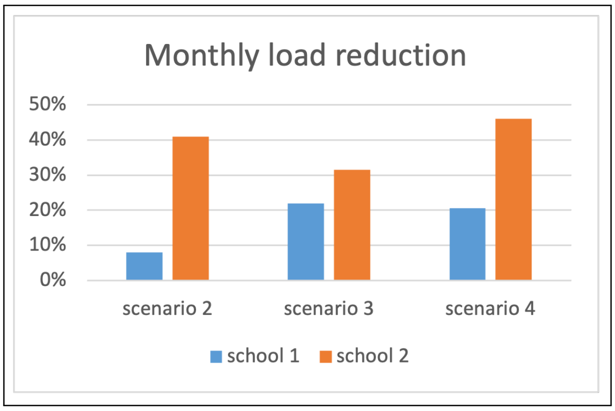

Figure 18: Heat loss reduction

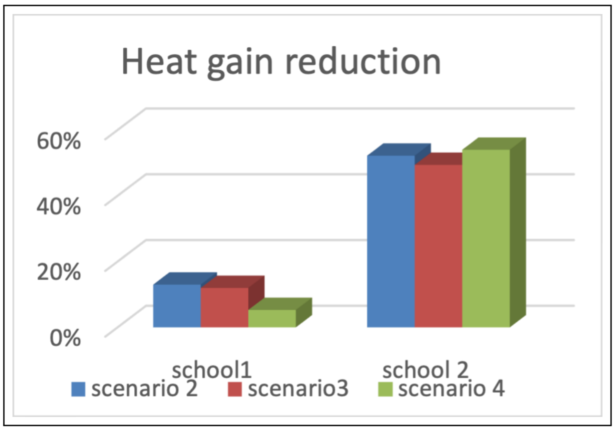

Figure 19: Heat gain reduction

scenario 2, 49.5% for scenario 3 and 54% for scenario 4.

Table above shows comparison of comfort temperature with existing research in summer. Figure above shows summary of studies of thermal comfort conducted in the different areas to evaluate thermal comfort status of students in the different school buildings. The research has been carried out in the different regions like japan, Pakistan and different places of Nepal. From the several studies it is clear that adaptive thermal comfort is crucial in the school buildings. The comfort temperature for Nepal lies between 21.1(°C)-30 (°C) from the Nichol thermal adaptive comfort model. This study found the same value of thermal comfort i.e 20.3°C-28.6°C.

Table 9: Comparison of comfort temperature for diffrent area

Area	Reference	Tc (°C)
Japan (Gifu)	Rijal et al.	26.1
Japan (Kanto)	Japan (Kanto)	27.6
Nepal	Rijal et al.	21.1∼30.0
Pakistan	Nicol and Roaf	26.7∼29.9
Nepal(Dang)	Bajracharya, S. B.	17∼27.6
Nepal(kathmandu)	Bajracharya, S. B.	18∼ 26
Nepal(Kapilvastu)	This study	20.3∼ 28.6*

4. Conclusion

This paper represents thermal comfort study which was conducted for the first time in case of school buildings in Kapilvastu district Nepal for summer season. The first objective was to report the thermal environmental conditions of classrooms in the schools of kapilvastu. The maximum average indoor temperature recorded in the Kapilvastu Vidhya Mandir secondary school (KVM) was 32°C, in the Udayapur school was 32.7 °C, and in Shainik shining English school was 32.4 °C.

The second objective was to find the comfort temperature of the study area. The comfort temperature which the people of Kapilvastu feel comfortable is 20.3°C , whereas the highest temperature in which the people of Kapilvastu feel comfortable is 28.6°.Third objective was to compare the effect of envelopes in uninsulated prototypical schools with thermally insulated. Insulations and material with lesser U-value can be good in order to achieve the better result for the thermal comfort in the school building. Heidar[13] . Estimates that each degree reduction in heating/cooling loads results in

7% energy saving. The heat gain data generated by the software were compared and analyzed. Material with lesser U-value can save 10-40% monthly heating or cooling load in summer than uninsulated buildings of Kapilvastu.

5. Recommendation

Insulations and material with lesser u-value are good in order to achieve the thermal comfort in the school building. While designing we should give concern for the comfort of the occupants and the adaptation of the buildings to the local climate. Passive and low-energy cooling solutions need to be incorporated in the design phase, in order to avoid mechanical cooling systems. It is recommended to designers to use the environment friendly materials to improve the thermal condition of the building.

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