Proceedings of IOE Graduate Conference, 2019-Summer
Peer Reviewed
Year: 2019 Month: May Volume: 6
ISSN: 2350-8914 (Online), 2350-8906 (Print)

Study of Thermal comfort in OPD block of Dhulikhel Hospital

Roshan Muni Tamrakar [a], Bharat Pahari [b], Sanjay Uprety [c]

[a, c] *Department of Architecture, Pulchowk Campus, IOE, Tribhuvan University, Nepal*
[b] *Department of Civil Engineering, Pulchowk Campus, IOE, Tribhuvan University, Nepal*
Corresponding Email: [a] rosann2164@gmail.com, [b] bharatpahari@gmail.com, [c] suprety@ioe.edu.np

Abstract
For smooth and efficient operation of medical services to the related personnel and the patients, the hospital has to provide comfortable efficient, healthy and comfort level. As thermal comfort varies with person to person, sex, health conditions, it can be adjusted by varying air flow movement, relative humidity, temperature, direct heat gains and active heating strategies. This research tries to study about the thermal comfort of the OPD block of Dhulikhel Hospital. Using Ecotect 2011 simulation tool, the building has been studied for comfort hours with ten years weather data provided by the Department of Meteorology and hydrology. The occupancy,sensible and latent heat loading that has been occurring in the hospital has been studied and applied accordingly. The air flow of 2 ACH airflow in the hospital room can decrease 1518 hours discomfort hour. This is the saving of using 1663 hours discomfort hours. In case of basement, as high air flow has to maintain the HVAC with high COP will provide the good result instead.

Keywords
Thermal comfort, Hospitals, Energy Performance Modeling

1. Introduction

In order to provide 24 hours medical services during the whole day of the year, the hospital needs to maintain a comfortable, efficient, healthy and safe comfort level to its personnel as well as the patients. As comfort varies with age, sex, health conditions, body shape as well as acclimatization of the individual person, thermal comfort deals with the satisfaction of the mind with the thermal environment. Thermal comfort can be achieved by adjusting air flow movement, relative humidity, temperature, direct heat gains and using passive and active adjusting strategies. In this context, The objectives of this research is to study the existing thermal comfort and to maximize the thermal comfort levels in Outpatient (OPD) block of Dhulikhel Hospital.

2. Literature Study

Indoor environmental quality in the hospital has a strong relationship with the thermal condition of the space which is directly affected by the amount of heat gain or loss. The factor related to heat gain and loss is building material used, external environmental conditions, temperature, humidity, air movements. A study Neale (2007) shows that thermal comfort range for standard room must be between 18 deg to 22 degrees.

Passively, the temperature can be controlled by using shading devices, controlling direct solar gain, air movements, creating buffer spaces, adding insulation. Humidity can be controlled by controlling surface area, insulating materials, creating buffer spaces and shading devices. Air movement can be controlled by using cross ventilation and stack ventilation. Active devices like HVAC, humidifier, fan boilers can be used for achieving thermal comfort.

Olgyay (2015) develop the ambient temperature and humidity with respect to human thermal comfort shown as a zone in the middle of the chart. The chart is successful in analyzing the conditions of the warm-humid climate only. Givoni chart combines different temperature amplitudes and vapor pressure of the ambient air plotted on a psychometric chart and correlated with specific boundaries of passive cooling techniques overlaid on the chart. The suggested techniques are ventilating cooling, air temperature reduction, evaporate cooling, and air conditioning. Further, Szokolays chart gives summer and winter comfort zone. This chart also suggests for the passive heating zone and active zone and direct and indirect cooling zone.

Before the introductions of mechanical ventilation, natural ventilation was the primary mode of ventilation used in hospitals (Ashrae,2010). For requirement of natural ventilation and daylight, maximum size windows has to be used, In recent times the natural ventilation is replaced by using mechanical ventilation in both developed and developing countries. With green building energy management concept, natural ventilation is the best way for evaporative heat loss from the building

The benefits of simple natural ventilation are limited by practical considerations since simple natural ventilation is only effective up to a depth of about 2.5 times the ceiling height, and the size of the window openings are constrained for safety reasons (Lomas,2009).

Air movement can generate cooling of occupants by increasing heat loss by both convection and evaporation. An air speed between 0.4 and 3.0 m/s is recommended for naturally ventilated spaces in hot and humid climates (Yeang,2006).

While the thermal comfort is an important aspect for the average user of a building, it becomes a critical aspect when it comes to population highly sensitive to thermal conditions. Children under and patients in hospitals with low levels of immune system are more likely to feel discomfort under certain operational conditions of ventilation, cooling and heating delivery systems (Auliciems,1997).

The ventilation system in large commercial buildings is widely used to transport heated and cooled air. Since the volume of air required to fulfill this task is frequently several times larger than the fresh air requirement, a significant part of the ventilation air is recirculated. Where re circulation is undesirable, thermal and latent heat recovery systems are used to recapture losses and used to precondition the supply air stream. For official building it was found that the shared type office is thermally comfortable than open type office.

Internal gains arise from the heat generated by the occupants, lighting and machines etc. used within the space. Depending upon the source sensible heat gains will be both convective and radiant in nature. Latent gains are mainly due to occupants; however there are some spaces such as swimming pools and kitchens where latent gains are more significant. In addition to being dependent upon the purpose of the building they may depend upon used patterns.

Installing mechanical fans instead of air-conditioning for improving the comfort of naturally ventilated buildings not only reduces the energy consumption, but also provides thermal comfort at higher temperatures by increasing the ventilation rate in classrooms. Reviewed studies reveal that classroom temperatures were controlled better when they were ventilated by mechanical system and/or by automatically operable window(s) with exhaust fan, allowing achieving cross-ventilation, compared to classrooms ventilated with manually operable windows.

3. Research Context

Generally, the hospital contains outpatient department and inpatient emergency department. This paper aims to study only the thermal comfort of the outpatient department. The OPD block consists of two basements and six storey buildings. This building serves all the outpatient services to the patients. The building has been laded in such a way that the staircase leads to the EV hall (waiting hall) the reception and waiting area is separated by aluminum glazing partition. In reception, there will be an only receptionist and three four visitors. From reception, patients can be accessed to the required clinics.

4. Methodology

This research adopted experimental research using Ecotect simulation software (version 2011) to simulate existing OPD of Dhulikhel Hospital. For this, a weather file in *.wea format was generated using ten years weather data obtained from the department of hydrology and meteorology. Drawings, occupancy, and equipment along with the orientation and other building features were studied in the field. The comfort hours derived from modeling of the existing case was verified by using a structured questionnaire in Kobo Toolbox. A total of five responded doctors of various departments were interviewed to verify thermal sensation with comfort hours derived.

5. Data and analysis

Ten-year data from 2008-2017 is taken from the Department of Hydrology and Meteorology. The

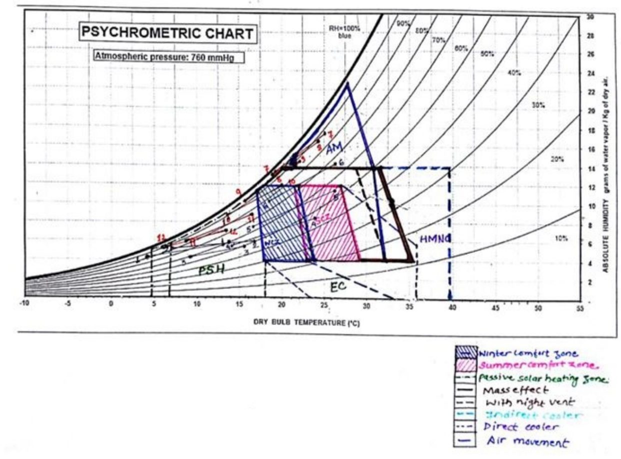

Figure 1: Psychrometric Chart

average maximum temperature 26.8oC was found in June and the average minimum temperature of 35.8 oC is found in January. Similarly, the relative humidity is maximum of 95.4 percent in August and the lowest 55.9 percent in April. The maximum rainfall occurs in mid of June with precipitation of 344 mm. and minimum occurs in mid of November with an 0.4 mm. From the end of February to the end of August, the velocity of air seems to be higher than 1m/s. The wind speed is higher during summer and low in winter periods. AEPC guidelines 2011 show the average yearly solar radiation in Dhulikhel is 6.5 KWh/m2/day.

Out of the literature reviewed processes for thermal comfort, as Szokolays chart provides summer comfort zone and winter comfort zone and more processes, this research uses this chart for the study of thermal comfort issues.

From this chart, a few days from April to October lies in comfort zone as it does not require heating and cooling. Mass effect is needed from April to June and August to October. The mass effect with night ventilation is required from April to October. Air movement need to be provided from June to September as humidity may be a problem when humidity exceeds about 70 percent. Evaporative direct cooling is required from April to June and from August to October. Evaporative indirect cooling is required from April to October. Passive solar heating is needed throughout the year. For a few days of January, active heating is necessary. Manohey chart shows that only light insulated walls and roofs are sufficient in this weather area.

The basement II consists of the radiology department,

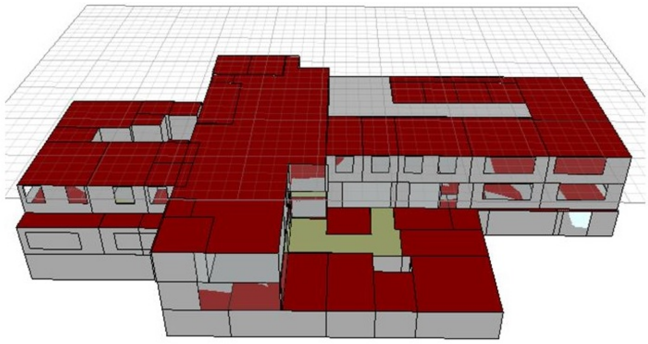

Figure 2: Replication of OPD block of Dhulikhel Hospital

where the equipment load is high, and airflow is minimum as there is only one opening and stack ventilation over staircases. The ground floor consists of cash counter, pharmacy and orthopedics block. As, there is pharmacy and registration section, the occupancy level will be higher than the other floor. As top floor is highly exposed to climatic portion. So, this three storey has been modelled in ecotect.

For replication of the Dhulikhel hospital, the modeling has been done in Ecotect. Dhulikhel hospital has two storey basement and six storeys above the ground floor.The floor height is 3.3 m while the false ceiling level is 2.77 m. Modelling is done with false ceiling height as the zonal volume will be different.

From BasementII to Basement, the exterior walls are shear wall with tile cladding. The tile cladding followed with 230mm brickwall is exist from ground floor to first floor. For remaining floors, the walls are just made up of 230 mm brickwall followed with plaster. The roofing is constructed by placing tile flooring follwed by 60 mm screeding and 125mm concrete,530 mm airgap and 12 mm gypsum cement fiber board.Internal partition consist of 345 mm wall with plaster, in case of x ray room, MRI, and CT scan. For insulation, internal partition are made with 115 mm followed by thermocol and cement fiber board, and double sided cement fiber board.

In replication of modeling, the room partition has been classified as each zone. The actual condition of the room size and the opening sizing has been placed. The placement of staircase portion is kept as void so that there will be clear function of air flow in the room.

The operating hour of Dhulikhel Hospital is 9-6 pm. The schedule in Ecotect has managed accordingly. The questionnaire has done of february 26, 2019. As,

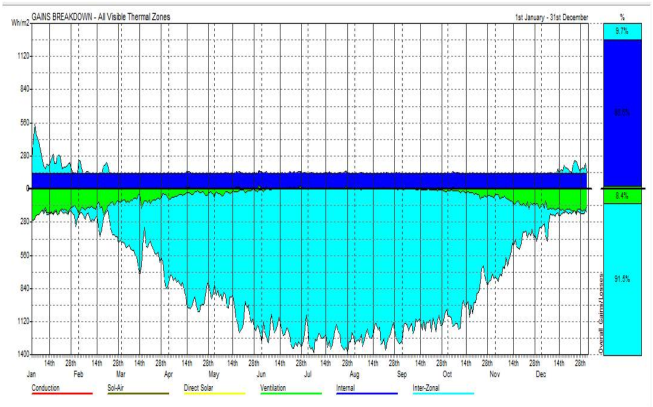

Figure 3: Passive Gain Breakdown in Existing Condition of Upper Floor

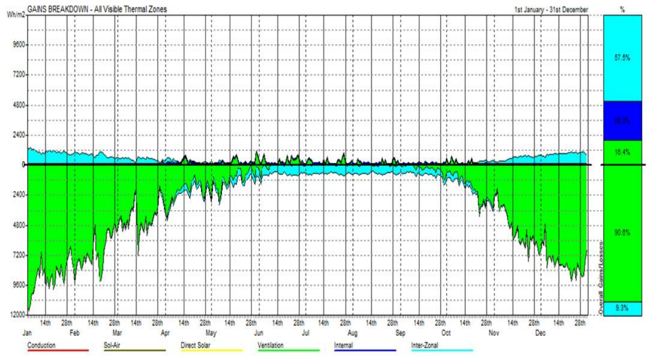

Figure 4: Passive Gain Breakdown When ACH=25

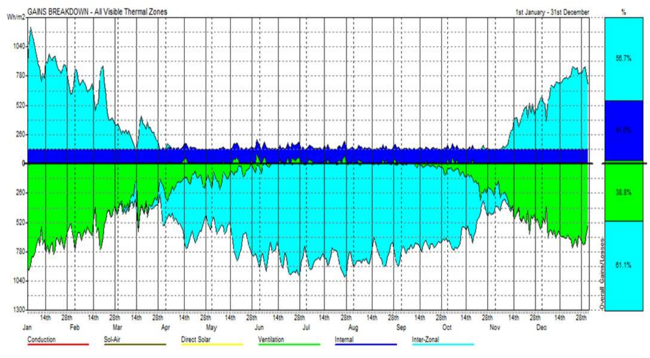

Figure 5: Passive Gain Breakdown When ACH=2

the temperature is cold, the occupants are wearing sweater and jacket. The number of occupancy in other clinics are inserted using Indian public health service guidelines. For lobby, waiting and sub waiting area the occupant are calculated according to the average number of people on that date at three different time period of the day.

The sensible loading is defined as the total lighting load per unit area. The sensible loading was found to be less than 2 w/ sqm. in upper floor and 7.2 w/ sqm in basement. Since, the default value for sensible loading is 2 W/ sqm, the sensible loading of 2 W/ sqm is kept for upper floors and 7.2 w/ sqm for basements.

The lateral loading is defined as the total equipment load per unit area. The lateral loading was found to be less than 3 w/ sqm. in upper floor and 6.1 w/ sqm in basement. Since, the default value for lateral loading is 5 W/ sqm, the sensible loading of 5 W/ sqm is kept for upper floors and 6.1 w/ sqm for basements.

Since, there is too much partition the inter-zonal heat gain is too much high. This occurs as the heat generate in the room cannot escape from the room. This can be improved by increasing air flow.

As in the case of basement there is only one opening and the air would pass through only one door to the staircase void. Modelling is divided into upper floor and basements.

The ecotect gives the airflow range from As the air flows change to 25 ACH, the ventilation rate increase drastically. The ventilation rate is higher than the interzonal heat transfer For economical air flow rate, it would be better if the interzonal heat transfer is equal to ventilation flows. So, using trial and error method. It was found that the air flow rate at 2 ACH, the both parameter seems to be equal.

When there is balance between interzonal heat gain and ventilation flow rate. There will be an optimisation of ventilation. This will increase the thermal comfort level in the study area as well.

Table 1

Month	ACH=1	ACH=20	ACH=2
Jan	0	0	0
Feb	3.38	0.35	0
Mar	30.05	2.6	2.11
Apr	183.46	6.62	4.29
May	266.26	25.22	14.8
Jun	280.09	57.52	115.01
Jul	289.61	45.07	103.61
Aug	289.44	26.48	69.25
Sep	279.04	5.24	10.97
Oct	201.35	10.14	5.06
Nov	18.81	1.69	1.13
Dec	2.24	0.04	0
Total	1844.4	181	326.2

From the discomfort hour perspective, the thermal comfort in existing case has 1844.4 hour discomfort hours in summer and 1034.3 discomfort hout in winter. Using only 2 ACh per hour in room, it was found that

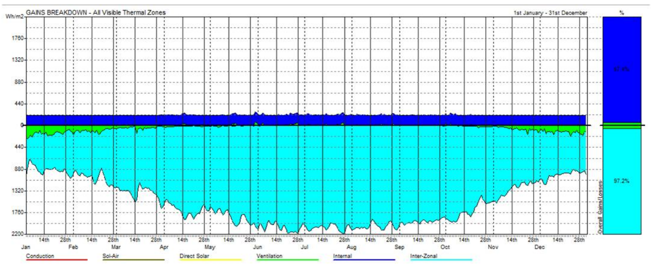

Figure 6: Passive Gain Breakdown existing case in basement

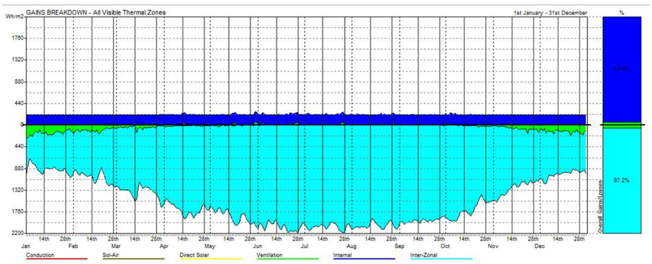

Figure 7: Passive Gain Breakdown when ACH= 25 in basement

the dicomfort hours in summer is 181 hours. So there will be 1663 hours of thermal comfort in the room. This increase hour of thermal comfort leads to the hvac energy saving of 1553 hours. As opd block is not much sensitive to temperature, it is easier to maintain air flow in the OPD block of Dhulikhel Hospital.

In case of basement, there is discomfort period with fully interzonal heat loss. As we increase the air flow change to 25 ACH, the ventilation rate increases a little bit. When ACH is 50 ACH, the ventilation rate increase and thermal comfort ranges also increases. As it is basement it will be harder to supply the air flow in the rooms. It would be better if we could use HVAC instead.

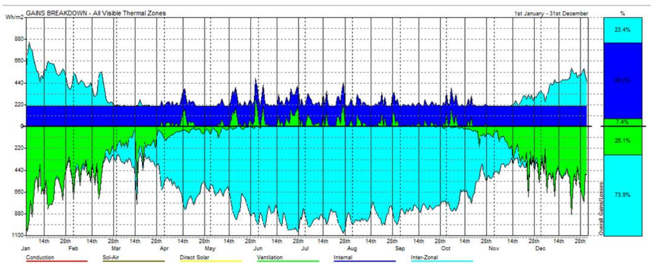

Figure 8: Passive Gain Breakdown when ACH= 50 in basement

6. Discussion

As per Manohey chart, the light insulated roof and wall is sufficient. The heat transfer through building envelope is negligible.

The passive heat gain breakdown shows that the average heat gain is due to the internal heating equipment like equipment loading and occupancy load. A minor portion of inter-zonal heat that means In heat gain occurs through the adjacent room. The heat loss in the building is highly due to the internal zonal heat loss. A minor portion of heat loss is due to ventilation problems. This chart shows the 4-inch internal partition is not sufficient in the hospital. It will recommend using insulation with a lower U value.

For maintaining discomfort in basement , 50 ACH airflow is required. Practically, the hospital partition is too small, ducting and exhaust system has to be introduced in this case for achieving thermal comfort, it is preferable to use HVAC with high COP values.

OPD block is designed for public patients. The air tightness is not much sensitive as compared to the air flow to the other floor of the buildings. The 2 ACH can easily be maintained by slightly opening windows.

Further, the hospital is equipped with HVAC in clinics as well as receptions for achieving comfort level. HVAC must be provided In the thermal sensitive room such as laboratory, MRI rooms etc.

The airflow management is also the difficult task as there is huge partition in the hospital. The negative pressure has to be maintained in the hospital room as the infected contaminated bacteria cannot be pass to the related boundary.

The fresh air supply has to be provided in case of basement as there is very less airflows.

In a questionnaire survey with the experienced doctor for more than 4 years in that hospital, the comfort level of the official staff, it is found that most of the sample used has slight hot slight cold. The period from Mansir to Falgun must require heating and Baisakh to Ashad must require cooling.

7. Conclusion

The air flow of 2 ACH airflow in the hospital room can decreases discomfort hour of 1518 hours in summer and increases 708 hours in winter. It is the saving of

811 hours comfort hours in the hospital per year.

References

[1] Adam Neale, Dominique Derome, J Carmeliet, and BJE Blocken. Coupled simulation of vapor flow between air and a porous material. In *10th International Conference on Thermal Performance of the Exterior Envelopes of Whole Buildings (Buildings X)*, pages 1–11. ASHRAE, 2007.

[2] ANSI ASHRAE. Standard 55-2010: Thermal environmental conditions for human occupancy. 2010. *American Society of heating, Refridgerating and Airconditioning Engineers: Atlanta*, 2010.

[3] Victor Olgyay. *Design with Climate: Bioclimatic Approach to Architectural Regionalism-New and expanded Edition*. Princeton university press, 2015.

[4] Andris Auliciems and Steven V Szokolay. Thermal comfort. PLEA, 1997.

[5] Kevin John Lomas and Yingchun Ji. Resilience of naturally ventilated buildings to climate change: Advanced natural ventilation and hospital wards. *Energy and Buildings*, 41(6):629–653, 2009.

[6] Ken Yeang. Ecodesign: A manual for ecological design. 2006.