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Evaluation of Thermal Comfort and Ventilation in General Patient Room of Godawari Midcity Hospital

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Abstract
Hospital is an important public buildings in which ventilation, room temperature and humidity inside a room plays an important role during the recovery phase of a patient. General patient room are usually in high demand in context of Nepal in comparison to other deluxe rooms. Various standard about room temperature and humidity for hospitals were studied to determine thermal comfort and discomfort hours. During the selected hospitals survey in Kathmandu and Lalitpur on ventilation and thermal comfort standards for general patient room, it was vivid that it is not up to the required standards. The study investigated on the total discomfort hours under natural ventilation and total heating and cooling loads required for a general patient room under mixed mode of ventilation in the Godawari Midcity Hospital in Lalitpur. Comparing various standards with each other shows that higher heating load is required to meet the thermal comfort level of IS 659 standard. Further, in the general patient room, there was ventilation losses of about 25% and increased to 80% according to ASHRAE 170 ventilation standard and IS 659 standard respectively. In addition, for south orientation a total of 90kWhr/m^2 of heating and cooling is needed which is the least among all the scenarios analyzed with north orientation of the building being the worst. As for WWR, 20% openings gave the best possible result as the higher WWR increased the heating and ventilation load. It is clear that the use of natural ventilation is not enough to maintain the thermal comfort in the room in both summer and winter seasons. Therefore use of mechanical ventilation is required and passive strategies can reduce the load in a certain extent.

Keywords
Hospital, Ventilation, Thermal Comfort, Passive Design

1. Introduction

Healthcare facilities and hospitals have different indoor environment due to various needs of patients and occupants in the hospitals. The indoor room environments differ from rooms to room in a hospital. It varies according to the room as patient rooms require different environment as compared to operating rooms, X ray rooms, isolation rooms, etc. In the present context ventilation in healthcare facilities is of much concern. Generally, the ventilation requirements for buildings and rooms are followed according to regulation, building codes, governments policies, etc. These requirements differ according to the climatic conditions, geographic location and economic background of the country. [1]

Passive design strategies are the major techniques to maintain the thermal comfort in the room and natural ventilation is one of the way to maintain the temperature in the building. Building orientation, window to wall ratio (WWR) and windows shapes also plays a factor in controlling the ventilation of the place. Natural ventilation is found to decrease the heating loads by cooling the room if effective measures are applied during the time of construction. [2]

2. Literature Review

The hospital has to provide comfort and efficient health care to the patients for proper care of the patient. Thermal comfort differs from people to people according to the person's age, sex, health conditions. Airflow in a hospital is an essential task and it has to be maintained according to the needs of the room either by maintaining positive room pressure or negative room pressure. Ventilation is a must in hospitals and should be managed naturally and if not enough mechanical ventilation must be provided. [3]

There are a lot of literature covering area of thermal comfort in general buildings but in hospitals the study regarding this topic is still not focused. It is essential to address the thermal comfort conditions required by the patients, attending workers and the caregivers. There needs to be focused studies on environmental parameters such as indoor humidity, air movement and temperature along with the variations of infections caused due to the change in these parameters.[4]

Various rooms in the hospitals require various values for internal parameters like pressures relationship with adjacent areas, minimum Air changes per hour, air re-circulation, relative humidity, desired temperature,etc. For a general patient room a maximum of RH of 60% and design temperature of 21.67-22.89^o C is required with a minimum of 2 ACH of ventilation. There is not any pressure relationship to the adjacent areas.[5]

Hospitals have a high energy demand mainly due to HVAC and minimizing the loads is one of the important goals for saving the energy costs. Humidity levels and indoor temperatures are cause of human discomfort and result in high HVAC use. By following a proper energy model using glazed windows, insulation materials, lighting devices and performing an economic analysis can find a possible solution for indoor thermal comfort and using less energy. [6] The ventilation requirements for spaces are to be formed according to the building codes, regulations and specific guidelines given by the local health authorities and others and this varies from zone to zone in same country as well due to climatic variations [7]

For the climate of Lalitpur, according to mahoney table the orientation of the building should be north and south, the walls and the floors should be light and have a low thermal capacity. The openings should be 20-40 % and the openings should be provided in South and North walls at body height on windward side. [8] In the climate of Lalitpur, which lies in the temperate region passive heating strategies are useful to maintain the thermal comfort in the cold months and air movement is considered useful for hot months to maintain the room cool. [9]

3. Methodology

The methodological approach of this research starts with literature review which includes preliminary study of the topic and is followed by field visit and base data collection. It is followed by climatic analysis of the place, determination of scenarios and modelling and simulation of the room . The data of temperature and humidity are collected from Department of Hydrology and Meteorology. The modelling and simulation analysis is done through Ecotect software and climatic data is also verified. Various scenarios regarding internal room temperature and the different steps involved in methodology of this research is shown in fig 1.

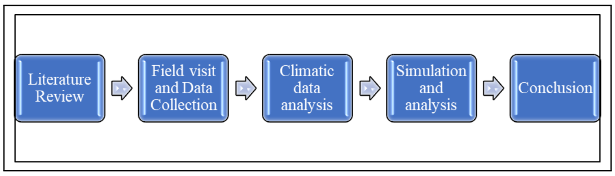

Figure 1: Methodology process

4. Research Context and climatic data analysis

There are about 125 hospitals in Nepal and 33 hospitals lie in Bagmati province (MOHP,2074). The hospital consists of indoor patient room, outdoor patient department, emergency services, X-ray departments, etc.Various hospitals were visited for the study of ventilation in the general patient room like Kist hospital in Imadol, godawari mediciti hospital, nobel hospital, B and B hospital, Patan hospital, Teaching hospital Kanti bal hospital, Bir hospital, etc. Among them GMC hospital which is located in Lalitpur was selected for study and analysis of ventilation and thermal comfort levels inside a general patient room.
The ten-year climatic data of the temperature and relative humidity from Department of Meteorology and Hydrology was taken and analyzed. . The data was recorded on daily basis. The monthly average value was taken in every month. The Ecotect software uses a epw file for climatic analysis of the building. These two data-sets are compared for relative humidity and temperature. An average difference of 1.48^{o}C temperature and an average difference of 7.95‰ relative humidity is seen when the comparison is made between monthly difference in the data from DHM and weather file used for simulation in a year.

Hospital was visited various times for field study in June/July which is hot and humid season.From the data collected, the average indoor temperature was found to be 25.04^{o}C and outdoor temperature was found to be 25.88^{o}C and an average of 74.33% relative humidity was found for the time of data collection. The temperature was found to be a little high for the month of July with the average data and the humidity was a little low when compared with the DHM data.

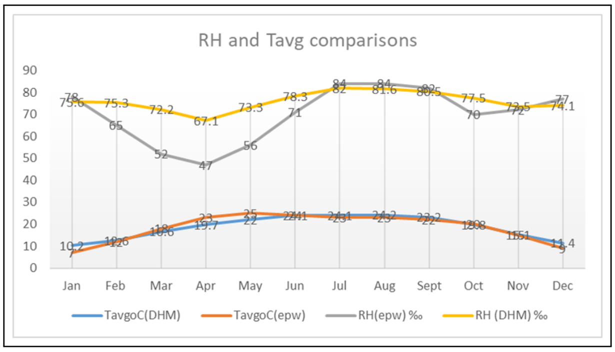

Figure 2: Relative humidity and average temperature comparisons

5. Modelling and Simulation

The patient room was modeled as it was in the base case scenario with the exact dimensions of room, floor height, windows position and other all related data along with the orientation of the room. The data taken for the simulation study is shown in the table below.

Table 1: Materials used and description

SN	Elements	Size
1	External Wall	354mm brick masonry
2	Window	3 @ 1.9m X 1.4m
3	Door	1 @ 1.2m X 2m timber
4	Glass	6 mm Single glazed
5	Roof	125mm RCC slab
6	Inner walls	230 mm c/s plaster
7	Floor height	2.5m

In the base model, the comfort band is set as 18^{o} C to 26^{o} C, humidity: 60% ; airspeed: 0.5 m/s, air change rate: 0.5 ACH. A total of 8 persons are considered for the room in resting phase.

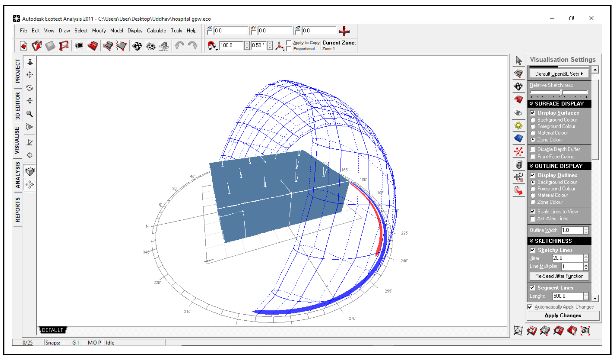

Figure 3: Base case model

The analysis is done in the following cases after modeling the base in Natural ventilation and mixed mode of ventilation in the zone settings.

5.1 Case 1 (ASHRAE 170 standard)

The patient room was modeled as it was in the base case scenario. In this case model, the comfort band given by ASHRAE 170 for general patient room and the temperature is set as 22.22^{o}C to 23.89^{o}C, humidity: 60%; minimum air change rate: 2 ACH is taken. A total of 8 persons are considered for the room in resting phase.

5.2 Case 2 (IS 659 standard)

The patient room was modeled as it was in the base case scenario with the exact dimensions of room, floor height, windows position and other all related data along with the orientation of the room. In this case model, the comfort band given by IS 659 in summer time is used for general patient room and the temperature is set as 23.9^{o}C to 26.1^{o}C humidity: 60%; minimum air change rate: 0.28m3/person is taken. A total of 8 persons are considered for the room in resting phase

5.3 Case 3 (Double Glazed windows)

In the base model, the comfort band is set as 18^{o} C to 26^{o} C, humidity: 60%; airspeed: 0.5 m/s, air change rate: 0.5 ACH. A total of 8 persons are considered for the room in resting phase. The only change made in this room is change of glass properties and the other settings in the room are as it is.

5.4 Case 4 (Increasing WWR)

In the base model, the comfort band given by neutrality temperature from the bio-climatic chart is set as 18^{o} C

to 26^o C, humidity: 60%; airspeed: 0.5 m/s, air change rate: 0.5 ACH. A total of 8 persons are considered for the room in resting phase. The only change made in this room is addition of a window in the southwest face of the room in the base model.
This case is further divided by increasing the WWR from 20-40 % along with the change in orientation.

6. Analysis and Results

The analysis of natural ventilation and mixed mode of ventilation is done.

6.1 Natural Ventilation

6.1.1 Total Discomfort Hours

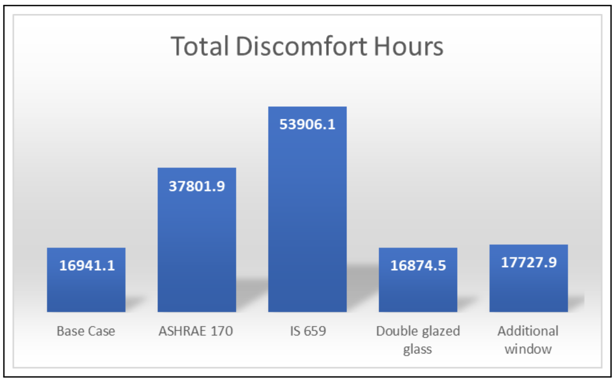

Figure 4: Total discomfort hours

According to this study, if we follow a standard temperature of thermal comfort as 18^{o}C to 26^{o}C then we find a total of 16941.1 hours of thermal discomfort in a year and for the same temperature if we change the room with double glazed glass windows in one case and add one additional window of the same size existing in the room there is not much of change in the total discomfort degree hours. But when follow the standard condition of thermal comfort according to ASHRAE 170 standard and IS 569 standard the discomfort degree hours are increased by double and four times the thermal discomfort degree hours compared to the base case.

6.1.2 Total ventilation gains

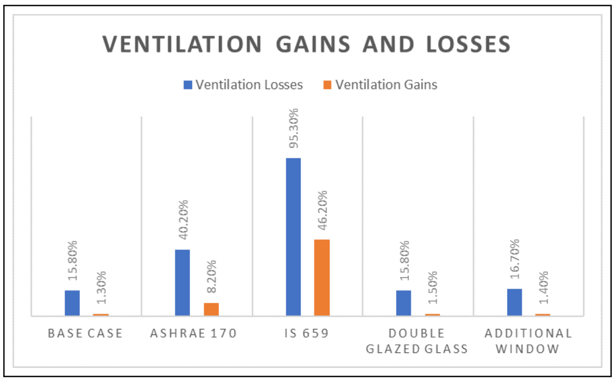

Figure 5: Total ventilation gains and losses

According to this study, if we see the base case and compare with other scenarios not much of difference is seen in the losses and gains in the ventilation for scenarios with double glazed glass and additional window but when seen with ASHRAE 170 and IS 659 standard the ventilation gains is nearly increased by 20% and nearly 80% respectively and the losses are also varied accordingly.

6.2 Mixed mode of Ventilation

6.2.1 Total heating and cooling loads

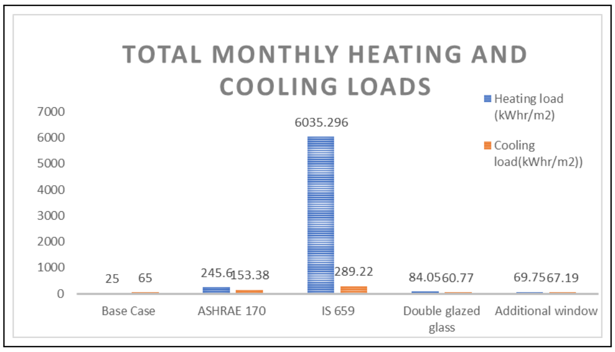

Figure 6: Total heating and cooling loads required

An average of 25kWhr/m^2 is needed as total heating load and 65 kWhr/m^2 is needed as total cooling load in a year and to maintain the thermal comfort accordingly the loads are increased in all the cases in yearly basis. IS standard shows a huge amount of heating load in order maintain the thermal comfort.

6.2.2 Total Ventilation gains and losses

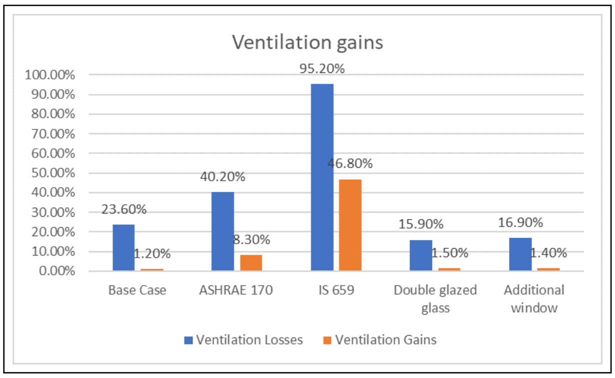

Figure 7: Total ventilation gains and losses for mixed mode of ventilation

According to this study, if we see the base case and compare with other scenarios a slight difference is seen in the losses and gains in the ventilation for scenarios with double glazed glass and additional window but when seen with ASHRAE 170 and IS 659 standard the ventilation gains is nearly increased by 17% and nearly 72% respectively and the losses are also varied accordingly.

6.2.3 Total loads due to orientation

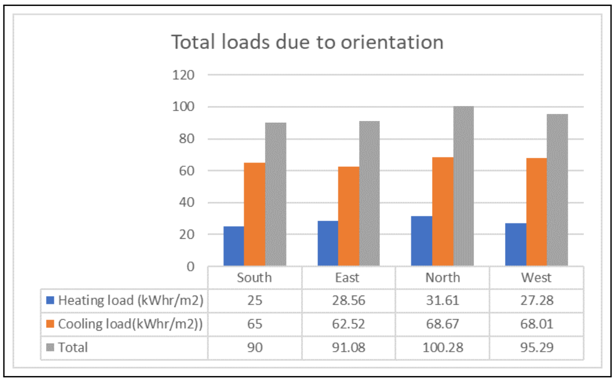

Figure 8: Total loads due to orientation

This graph shows the total loads comparison in the building when the buildings are oriented in four directions and the analysis shows that the best possible scenario for the building is South which is the existing case and then the worst possible scenario of the building is North.

6.2.4 Total loads due to WWR

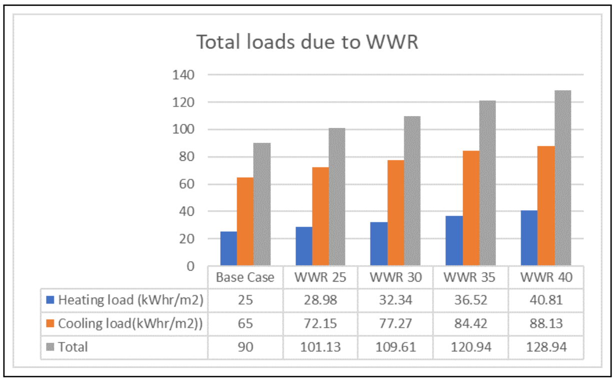

Figure 9: Total loads due to WWR

This graph shows the total loads comparison in the building when the building's Window Wall Ratio are changed and the analysis shows that the best possible scenario for the building is when the WWR is twenty percentage which is the existing case and then the worst possible scenario is when the WWR is forty percentage and WWR thirty percentage is also among the best case.

7. Findings and Discussions

There are many governmental and private hospitals in our country where various studies regarding energy saving and comfort can be done. Hospitals are busy sectors due to population growth and they just don't give us time for such research works. For this case study, various hospitals in Kathmandu and Lalitpur were visited to find out the ventilation in general patient room and the process of ventilation were asked in the general patient room. There is not such a guidelines from which the hospitals follow the temperature and humidity in the room and for a general patient room natural ventilation was mostly the option for the room.

Among the scenarios, two international standards ASHRAE 170 and IS 659 were taken for the study. The cases shows that the rooms are not comfortable thermally enough for the whole year with natural ventilation only and for this a huge amount of heating loads is required in the cooler months to maintain the room thermally comfortable. The thermal comfort temperature range for the rooms and the humidity to be maintained are mentioned in the standards and for them to meet in the hospital in this it requires heating and cooling loads in all the months. From the comparisons among the standards, IS standard requires the highest amount of heating and cooling loads. The room with south orientation is found to be the best one among the taken scenarios and 20 percentage WWR shows less loads consumption when the room is naturally ventilated. The change in materials of the room and increasing Window Wall Ratio also doesn't show much improvement to decrease the heating and cooling loads. So, to maintain the patient's room comfortable for patients, a study is needed to find out requirements of humidity, ventilation and patient room according to the climate and mechanical ventilation if required should be provided to make the patient heal faster.

8. Conclusion

The major objective of this research was to evaluate thermal comfort and ventilation in a general patient room in a hospital building. This has been achieved by taking a general patient room of Godawari Midcity hospital in Lalitpur. The thermal comfort study was conducted using Ecotect software where modeling of exact and various scenarios was done. Finally, it is clear that the use of natural ventilation is not enough to maintain the thermal comfort in the room in both summer and winter seasons. To maintain thermal comfort an average of 25 kWhr/m^2 is needed as total heating load and 65 kWhr/m^2 is needed as total cooling load in a year for the base case. Also, if we follow the standards of ASHRAE 170 and IS 659 the thermal comfort is maintained only by the use of mechanical ventilation along with the natural ventilation. The loads to maintain the ASHRAE 170 standard is about 245.6 kWhr/m^2 as total heating load and 153.8 kWhr/m^2 as total cooling load in a year. Use of proper passive designs like use of Orientation and WWR in a proper way can reduce the heating and cooling loads in the room and maintain the thermal comfort.

There are a few recommendations that can be done further. One of the first study that can be done is to find out the thermal comfort temperature, ventilation requirement and humidity requirement for the patient room and in various other rooms like isolation room, OT room, X ray room, Emergency room, etc. and create a standard document in the context of our country and climatic conditions. Various passive strategies for the building and the ways to improve natural ventilation can be studied further. The impacts of vegetation in increasing the ventilation can be studied further. As there are few studies which are carried out regarding these topics, researchers can look further inside such topics and study in a proper way.

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