Thermal Comfort-IDP

Neelesh-Eslam-Rohit-Kunal-Shashank

Group 1

Energy Engineering Dept.

Brief summary of the group project for the module IDP

Technische Universität Berlin

July 2020

Contents

Introduction 3
Goal 3
Theory 3
Methodology 5
Inputs 5
Assumptions 5
Data extraction 5
Observation from data set 5
Observation 10
Calculations 11
Equations 11
Results 13
References 14

Figure 1: Different construction materials [1] 3
Figure 2: Solar radiation and sun position [2] 4
Figure 3: Rohit's temperature variation 6
Figure 4: Rohit's humidity variation 6
Figure 5: Rohit's heat variation 7
Figure 6: Kunal's temperature variation 7
Figure 7: Kunal's humidity variation 8
Figure 8: Kunal's heat variation 8
Figure 9: Shashank's temperature variation 9
Figure 10: Shashank's humidity variation 9
Figure 11: Shashank's heat variation 10
Figure 12: Final observation 10

Introduction

Goal

Selecting the appropriate comfort temperature became increasingly important in the 21st century. Therefore, architects and engineers are now concerned with selecting the suitable building material and wall thickness.

Taking this into consideration, we established a platform which provides recommendation to the user about the thickness of walls of particular construction type. This would help to maintain maximum probability of thermal comfort inside the building.

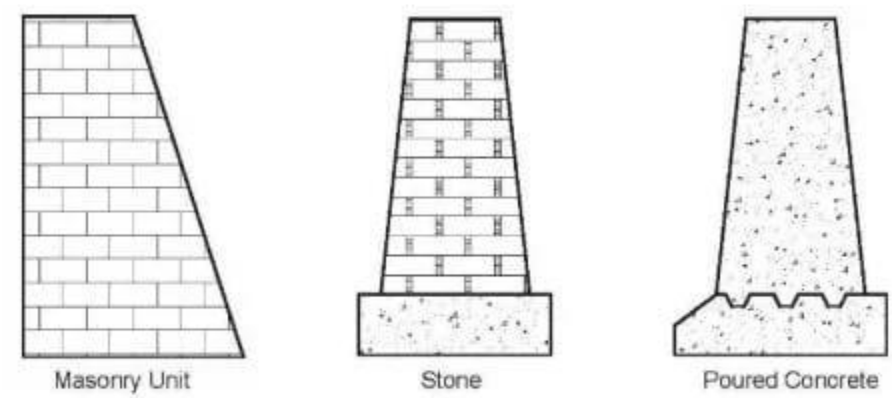

Figure 1: Different construction materials [1]

Theory

The first defense line against external thermal forces is the outer surface of the building. While the surface temperature of the building is usually higher than that of the air, careful treatment of the building surface is essential in order to reduce heat gain. Also, it’s important to select the appropriate emissivity and absorptivity characteristics of the surface materials to help reducing the impacts of the solar radiation.

While the dominant weather elements which affect the energy exchange are sunshine, air temperature, and wind, other factors like building shape and orientation, the absorptivity and emissivity characteristics of the surfaces are also involved into the energy exchange process. Therefore, it’s important to predict the energy exchange between the surfaces of the building and the outdoor environment.

While some might consider the effects of other factors such as rain, condensation and evaporation, we found that these factors are not always involved. Hence, we decided to overlook their effects on the energy exchange process.

The normal meteorological readings which are taken do not adequately describe the weather for purposes of calculating its effect upon the surface energy exchange, particularly when sunshine is involved. Even if all the individual factors are measured there remains the problem of recombining these multiple streams of variables in the calculation. There is, fortunately, a way of achieving some simplification; a combined factor called sol-air temperature can be used so that it becomes necessary only to deal with a single stream of data.

Sol-air temperature is a fictitious temperature which represents as defined by ASHRAE the temperature of the outdoor air that , in the absence of all radiation changes , gives the same rate of the heat entry into the surface as would be the combination of incident solar radiation , radiant energy exchange with the sky and other outdoor surroundings , and convictive heat exchange with the outdoor air. Sol air temperature helps us to calculate the temperature of outside walls which is most essential for our calculation.

Since personal comfort requirements vary from person to person, it becomes difficult to quantify a common thermal comfort characteristic for each person. We have decided to let the user define their own comfort criteria, and we provide them with results accordingly.

The required temperature and humidity inside the room from the user provides us with the basis of estimating inside wall temperature range. From our individual dataset of different type of construction and variation of temperature across the wall, we can formulate the change of temperature for different wall thickness. Applying this methodology, we can determine the different wall thickness of the building, such that the inside condition remains in thermal comfort. We calculate the mean thickness of wall, such that the probability of remaining in thermal comfort zone remains high throughout the year.

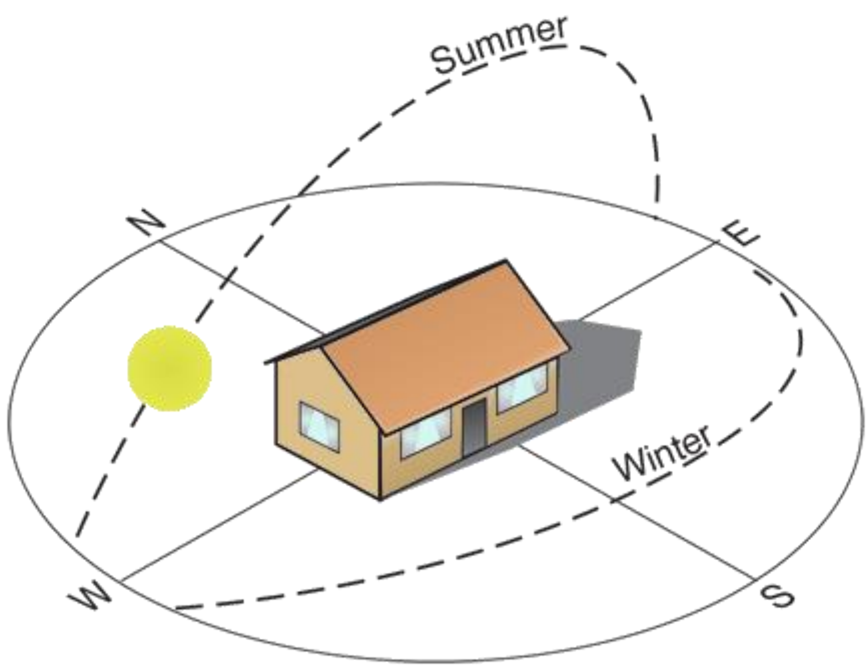

Figure 2: Solar radiation and sun position [2]

Methodology

Inputs

The web application requires the following inputs from the user:

- Latitude - Manual input
- Longitude – Manual Input
- Time-shift – Manual Input
- Nearest Weather station location – Interactive choice tool
- Material of construction – Choose from given options
- Orientation of house – Manual input
- Thermal comfort temperature range – minimum and maximum temperature – Manual input

Assumptions

1. No humidity (only thermal comfort considered)
2. No person inside the room
3. The floor is thermally insulated
4. Constant convection coefficient (wind velocity neglected)
5. No heat storage capacity
6. Steady state
7. T_{sol} is considered the outside wall temperature
8. The comfort range given by the user is in the center point of the room
9. No shading effects
10. The suggested wall thickness is uniform
11. Paint effect is neglected
12. Minimum allowed thickness=20cm, maximum allowed thickness=50cm
13. An average value of suggested thickness throughout the year

Data extraction

From the user input we can extract data useful for the calculation.

- Weather Station – We will extract ambient air temperature, relative humidity, Diffuse horizontal irradiation, Direct normal irradiation and wind velocity data for about a year (8760 hours)
- Data set from our observation – From the readings we take in our own personal environment, we form a relationship between variation of temperature and humidity across the building wall with the thickness. This data will be used in the calculation

Observation from data set

1. Rohit: Data For 12 PM to 12 PM (28 July – 29 July) (Berlin)

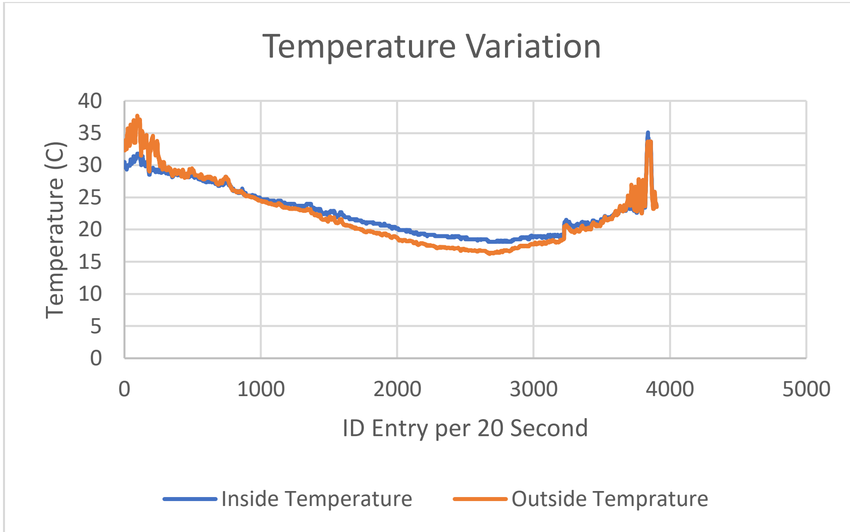

Figure 3: Rohit's temperature variation

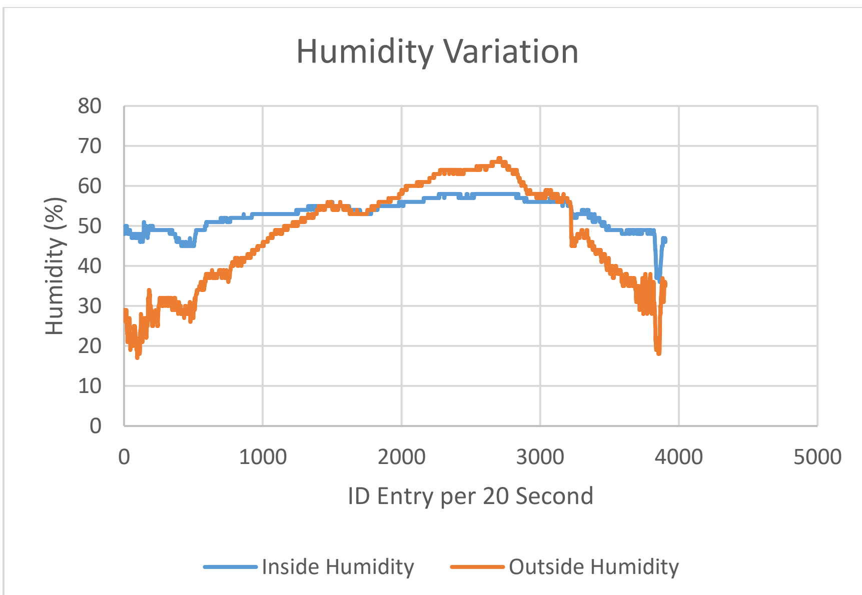

Figure 4: Rohit's humidity variation

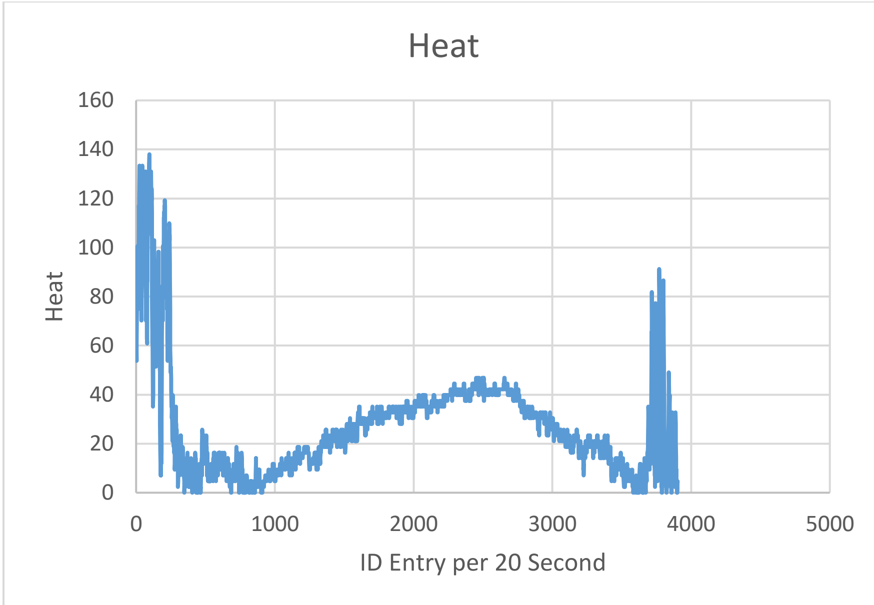

Figure 5: Rohit's heat variation

2. Kunal: Data For 12 PM to 12 PM (25 July – 29 July) (Berlin)

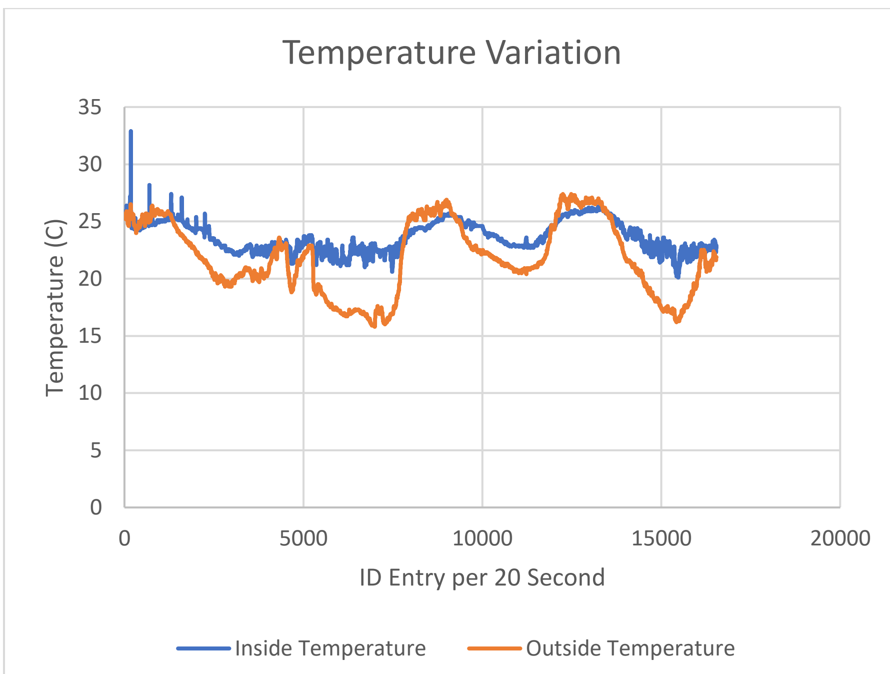

Figure 6: Kunal's temperature variation

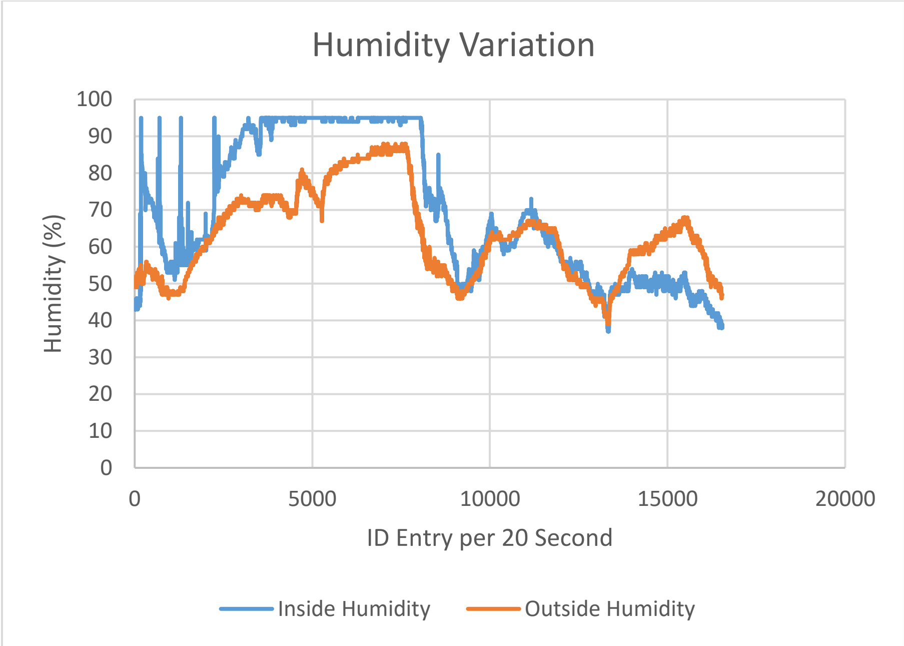

Figure 7: Kunal's humidity variation

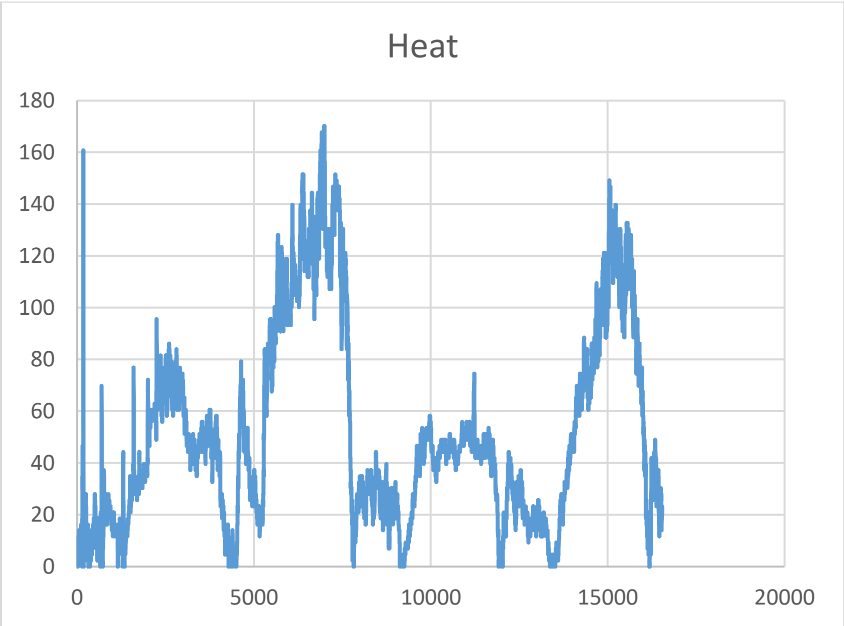

Figure 8: Kunal's heat variation

3. Shashank: Data For 12 PM to 12 PM (25 July – 29 July) (India)

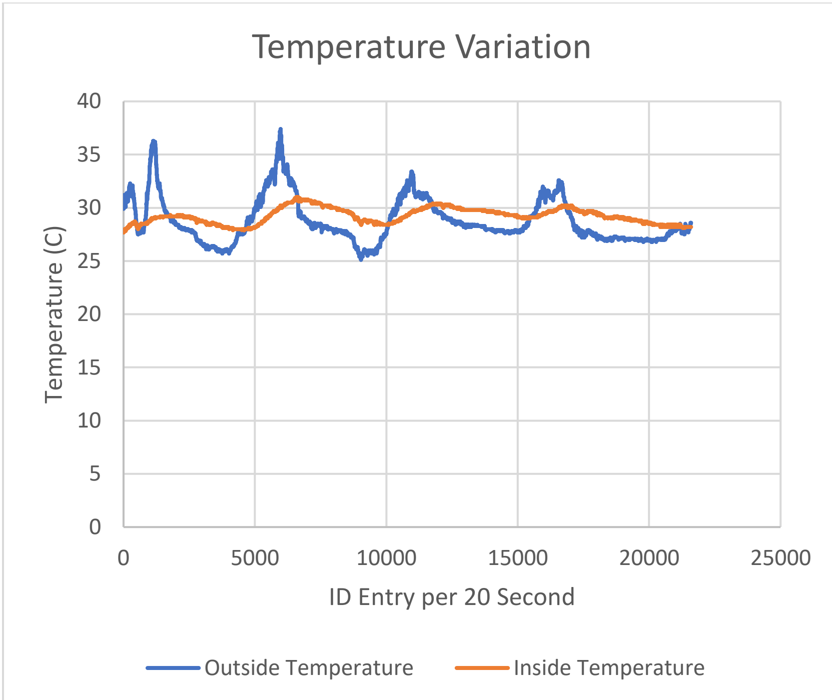

Figure 9: Shashank's temperature variation

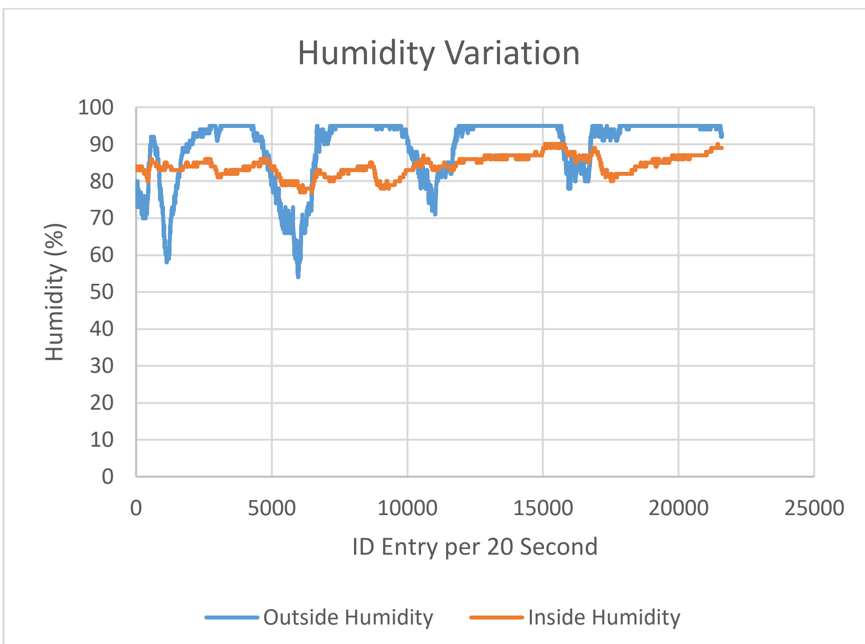

Figure 10: Shashank's humidity variation

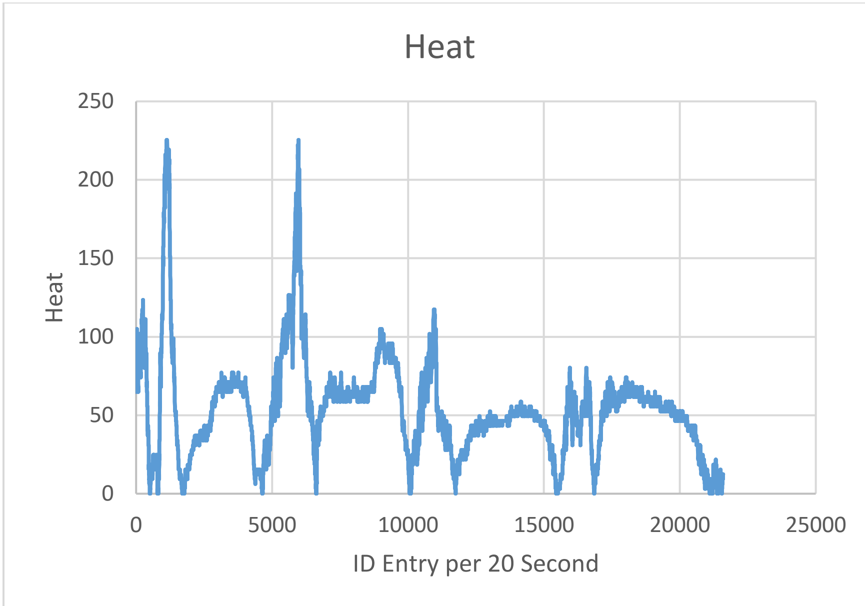

Figure 11: Shashank's heat variation

Observation

The Humidity difference is negative for the areas in low Outside Temperature which means the inside humidity is more compared to outside humidity. With High outside Temperature, the humidity difference is positive, which means that outside humidity is more than inside humidity. The increase in the outside temperature can account for more humidity.

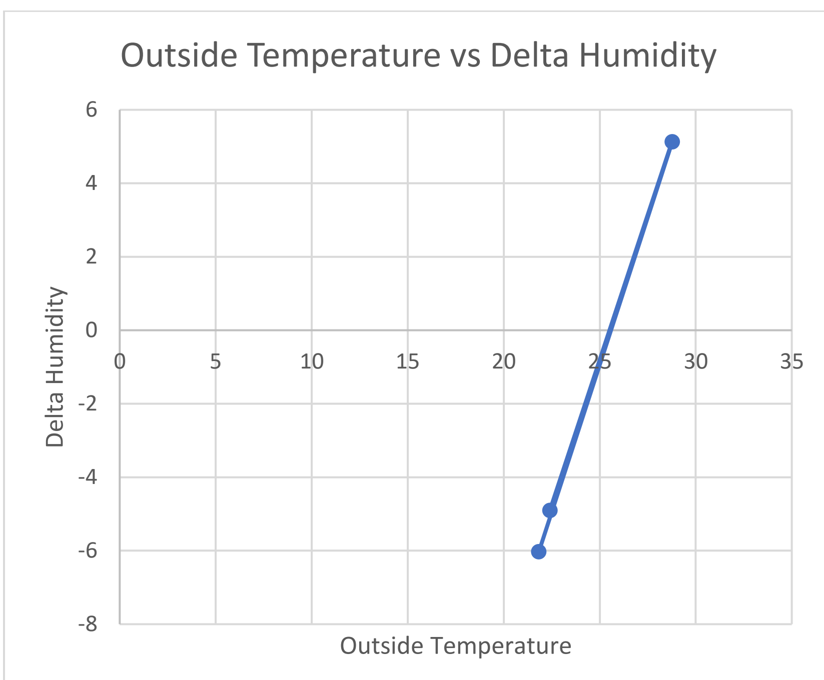

Figure 12: Final observation

Calculations

• Global Tilt Irradiance(W/m2) – We have to calculate amount of irradiation incident on each wall of the proposed building in order to calculate effect of the irradiation on wall temperature.

We collect the data of Direct Normal irradiation (DNI) and Diffuse Horizontal Irradiation (DHI) from the nearest weather station. From this we calculate GHI.

Solar Radiation differs in time and location due to earth rotation, reflection on and absorption in the atmosphere

- changes in radiation magnitude
- and elevation angle of the sun γs and azimuth of the sun angle αs 0° - North; 90° - East; 180° - South; 270° - West

The walls have fixed orientation

- inclination angle for 4 walls $\gamma E = 90$, and o degree for the roof
- azimuth angle of the surface αE

Once we know the orientation of the wall, we would know the azimuth angles of all the walls (0° - South; 90° - East; 180° - North; 270° - West).

Equations

Global Horizontal Irradiance

- GHI =Direct Normal Irradiance (DNI) * sin(γs) + Diffuse Horizontal Irradiance (DHI)

Global Tilt Irradiance

- GTI = tilt direct irradiance + tilt diffuse irradiance
- $GTI = [DNI * \sin(\gamma s)] * \cos(\Theta gen) / \sin(\gamma s) + DHI * 0.5 * [1+\cos(\gamma E)]$
- $\Theta gen = \arccos[-\cos(\gamma s) * \sin(\gamma E) * \cos(\alpha s - \alpha E) + \sin(\gamma s) * \cos(\gamma E)]$

Due to sun movement we have to calculate the solar position for each time (γs, αs)

For one day of a year:

Sun position:

- $J = 360° * day\ of\ year / days\ in\ one\ year$

Declination angle:

- $\delta(J) = 0.3948 - 23.2559 \cdot cosd\,(J + 9.1) - 0.3915 \cdot cosd\,(2 \cdot J + 5.4°) - 0.1764 \cdot cosd(3 \cdot J + 26°)$

Time equation:

- $teq\ J = (0.0066 + 7.3525 \cdot cosd(J + 85.9°) + 9.9359 \cdot cosd(2 \cdot J + 108.9) + 0.3387 \cdot cosd(3 \cdot J + 105.2°)/60$

For every hour:

Locale mean time:

- $LMT = UTC - 4 \cdot (15° \cdot timeshift - longitude)/6$

Local time:

- $LT = LMT + teq$

Hour angle:

- $\omega = (12\text{-LT}) \cdot 15$

Elevation angle of the sun:

- $\gamma s = asin(cosd\ \omega \cdot cos\ latitude \cdot cos\ \delta + sin\ latitude \cdot sin(\delta)$

Azimuth angle of the sun:

if LT <=12

- azimuth_angle((day-1) *24+UTC) =180-acosd((sind(elevation_angle((day-1) *24+UTC)) *sind(latitude)-sind(delta))/(cosd(elevation_angle((day-1) *24+UTC)) *cosd(latitude)));

else

- azimuth_angle((day-1)*24+UTC)=180+acosd((sind(elevation_angle((day-1)*24+UTC))*sind(latitude)-sind(delta))/(cosd(elevation_angle((day-1)*24+UTC))*cosd(latitude)));

Temperature of outside wall temperature:

- Tsol = Toutside + R * ($\alpha I_T - \varepsilon * I_1$)
  - Toutside – Environment temp (Weather station)
  - α – absorptivity depends upon the material
  - ε – emmisivity depends upon the material
    1. emmisivity_brick = 0.55
    2. absorptivity_brick = 0.93
    3. emmisivity_concrete = 0.65
    4. absorptivity_concrete = 0.96
  - I_T (in Win-2) is the intensity of direct plus diffuse solar radiation on the outer surface of the wall
  - I_1 (in W m- 2) is the intensity of long-wave radiation
  - R_wall=0.05 # m2K/W
    R_roof=0.04 # m2K/W

I_roof=100 [W/m2]
I_wall=0 [W/m2]

For Indoor condition:

- Trequired = [φw1→m * T w1 + φw2→m * T w2 + φw3→m * T w3 + φw4→m * T w4 + φwroof→m * T roof)+dbt_{air}]/2
  - T w – we know from our sensors and calculation

  view factor for person to outside:
  - Φw1→m = (A1/(A1+A2+A3+A4+A5+A6))

Inside wall temperature:

For concrete:

- Twall_inside=Tsol + ((4.7065*z)/100) (No radiation on outside walls)
- Twall_inside=Tsol - ((4.7065*z)/100) (Radiation on outside walls)

**DeltaT(avg)/Wall thickness=1.8826/0.4= 4.7065 (From our experimental data)

For brick:

- Twall_inside=Tsol + ((7.72*z)/100) (No radiation on outside walls)
- Twall_inside=Tsol - ((7.72*z)/100) (Radiation on outside walls)

**DeltaT(avg)/Wall thickness=1.93/0.25= 7.72 (From our experimental data)

Energy required for heating:

- Q_h= (Air density *(Volume of air inside room) *C_p(air)*delta_heat)/3600

Energy required for cooling:

- Q_c = (Air density *(Volume of air inside room) *C_p(air)*delta_cool)/3600

**delta_heat: minimum comfort temp. given by user-actual room temp.
**delta_cool: actual room temp.-maximum comfort temp. given by user
**Air density=1.225 [kg/m^3]
**C_p(air)=1 [kJ/kg]
** Volume of air inside room = (length-(2*(Thickness/100)))*(breadth-(2*(Thickness/100)))*(height-(2*(Thickness/100)))

Results

- We recommend thickness of the wall for the new building of particular type construction for maximum thermal comfort throughout the year without the use of auxiliary equipment.

- Probability of the Room being in comfort range for the whole year after using our provided thickness of wall construction (For chosen building Material) eg. 60 % of the time the room shall be in comfort range with concrete construction.
- Cooling/Heating media/Insulation requirement – Analysis for the particular season when the comfort range is disturbed and suggesting auxiliary unit such as either AC, Heat Pump or Ceiling fan.
- Psychrometric Chart visualization for the user showing the suggested room conditions in comparison to the comfort range (so that user can choose best construction).
- 3 – Dimensional visualization of the building.
- Illustrating how much energy would be spent on heating/cooling if the user uses the website suggestion. [kWh]

References

[1] https://theconstructor.org/wp-content/uploads/2018/09/Materials-used-for-gravity-retaining-wall-construction-450x202.jpg

[2] https://i.pinimg.com/originals/b8/15/0d/b8150d7a0b351d719dea2b9a22217794.png